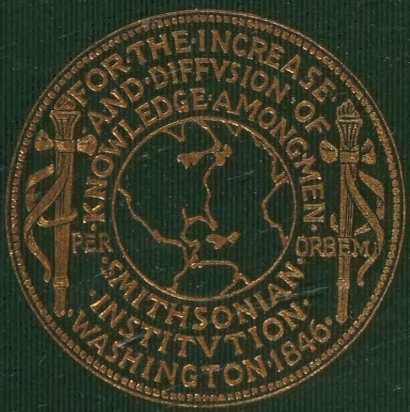
FOR THE INCREASE
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PER SMITHSONIAN
INSTITVTION
WASHINGTON 1846
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ANNUAL REPORT OF THE BOARD OF REGENTS OF

THE SMITHSONIAN INSTITUTION

SHOWING THE

OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR ENDING JUNE 30

1924

(Publication 2795)

WASHINGTON
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1925

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LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

SUBMITTING

THE ANNUAL REPORT OF THE BOARD OF REGENTS OF THE INSTITUTION FOR THE YEAR ENDING JUNE 30, 1924

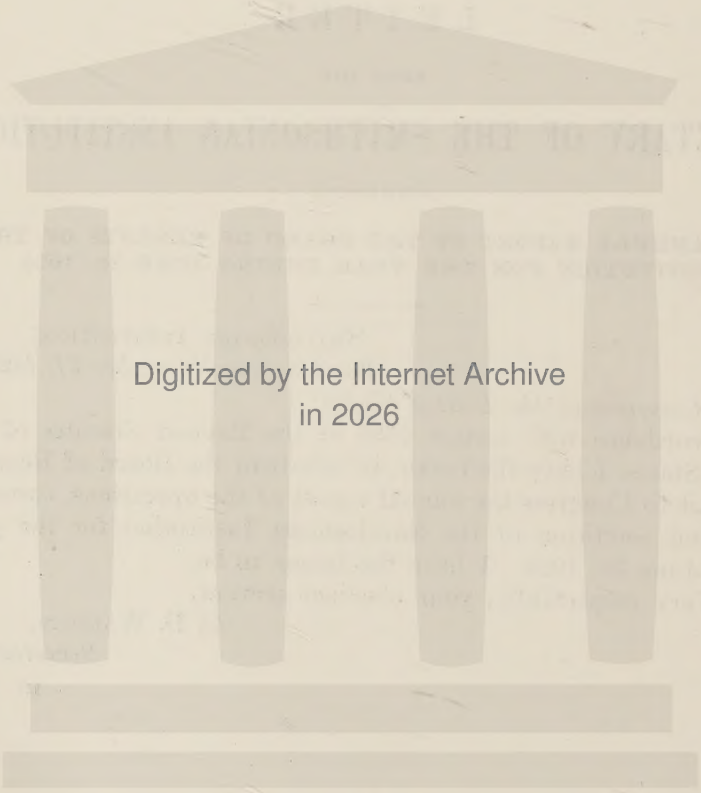
SMITHSONIAN INSTITUTION,
Washington, November 21, 1924.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1924. I have the honor to be,

Very respectfully, your obedient servant,

C. D. WALCOTT,
Secretary.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ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1924.

SUBJECTS

1. Annual report of the secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1924, with statistics of exchanges, etc.

2. Report of the executive committee of the Board of Regents, exhibiting the financial affairs of the Institution, including a statement of the Smithsonian fund, and receipts and expenditures for the year ending June 30, 1924.

3. Proceedings of the Board of Regents for the fiscal year ending June 30, 1924.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1924.

20397—25——2

THE SMITHSONIAN INSTITUTION

June 30, 1924

Presiding officer ex officio.—CALVIN COOLIDGE, President of the United States.
Chancellor.—WILLIAM HOWARD TAFT, Chief Justice of the United States.
Members of the Institution:

CALVIN COOLIDGE, President of the United States.
WILLIAM HOWARD TAFT, Chief Justice of the United States.
CHARLES EVANS HUGHES, Secretary of State.
ANDREW W. MELLON, Secretary of the Treasury.
JOHN WINGATE WEEKS, Secretary of War.
HARLAN F. STONE, Attorney General.
HARRY S. NEW, Postmaster General.
CURTIS D. WILBUR, Secretary of the Navy.
HUBERT WORK, Secretary of the Interior.
HENRY CANTWELL WALLACE, Secretary of Agriculture.
HERBERT CLARK HOOVER, Secretary of Commerce.
JAMES JOHN DAVIS, Secretary of Labor.

Regents of the Institution:

WILLIAM HOWARD TAFT, Chief Justice of the United States.
HENRY CABOT LODGE, Member of the Senate.
A. OWSLEY STANLEY, Member of the Senate.
MEDILL MCCORMICK, Member of the Senate.
ALBERT JOHNSON, Member of the House of Representatives.
R. WALTON MOORE, Member of the House of Representatives.
WALTER H. NEWTON, Member of the House of Representatives.
GEORGE GRAY, citizen of Delaware.
CHARLES F. CHOATE, Jr., citizen of Massachusetts.
HENRY WHITE, citizen of Washington, D. C.
ROBERT S. BROOKINGS, citizen of Missouri.
IRWIN B. LAUGHLIN, citizen of Pennsylvania.
FREDERIC A. DELANO, citizen of Washington, D. C.

Executive committee.—GEORGE GRAY, HENRY WHITE, FREDERIC A. DELANO.
Secretary of the Institution.—CHARLES D. WALCOTT.
Assistant Secretary.—C. G. ABBOT.
Chief clerk.—HARRY W. DORSEY.
Accounting and disbursing agent.—N. W. DORSEY.
Editor.—W. P. TRUE.
Assistant librarian.—PAUL BROCKETT.
Appointment clerk.—JAMES G. TRAYLOR.
Property clerk.—J. H. HILL.

THE NATIONAL MUSEUM

Keeper ex officio.—CHARLES D. WALCOTT, Secretary of the Smithsonian Institution.
Administrative assistant to the Secretary, in charge.—W. DE C. RAVENEL.
Head curators.—WALTER HOUGH, LEONHARD STEJNEGER, G. P. MERRILL.

Curators.—Paul Bartsch, R. S. Bassler, T. T. Belote, Austin H. Clark, F. W. Clarke, F. V. Coville, W. H. Dall, Walter Hough, L. O. Howard, Aleš Hrdlička, Neil M. Judd, Frederick L. Lewton, George P. Merrill, Gerrit S. Miller, Jr., Carl W. Mitman, Robert Ridgway, Waldo L. Schmitt, Leonhard Stejneger.

Associate curators.—J. M. Aldrich, C. W. Gilmore, W. R. Maxon, Charles W. Richmond, J. N. Rose, David White.

Chief of correspondence and documents.—H. S. Bryant.

Disbursing agent.—N. W. Dorsey.

Superintendent of buildings and labor.—J. S. Goldsmith.

Editor.—Marcus Benjamin.

Assistant librarian.—N. P. Scudder.

Photographer.—Arthur J. Olmsted.

Property clerk.—W. A. Knowles.

Engineer.—C. R. Denmark.

Shipper.—L. E. Perry.

NATIONAL GALLERY OF ART

Director.—William H. Holmes.

FREER GALLERY OF ART

Curator.—John Ellerton Lodge.

Associate curator.—Carl Whiting Bishop.

Assistant curator.—Grace Dunham Guest.

Associate.—Katharine Nash Rhoades.

Superintendent.—John Bundy.

BUREAU OF AMERICAN ETHNOLOGY

Chief.—J. Walter Fewkes.

Ethnologists.—John P. Harrington, J. N. B. Hewitt, Francis La Flesche, Truman Michelson, John R. Swanton.

Editor.—Stanley Searles.

Librarian.—Ella Leary.

Illustrator.—De Lancey Gill.

INTERNATIONAL EXCHANGES

Chief Clerk.—C. W. Shoemaker.

NATIONAL ZOOLOGICAL PARK

Superintendent.—Ned Hollister.

Assistant Superintendent.—A. B. Baker.

ASTROPHYSICAL OBSERVATORY

Director.—C. G. Abbot.

Aid.—F. E. Fowle, Jr.

Assistant.—L. B. Aldrich.

REGIONAL BUREAU FOR THE UNITED STATES, INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

Assistant in charge.—Leonard C. Gunnell.

REPORT

OF THE

SECRETARY OF THE SMITHSONIAN INSTITUTION

CHARLES D. WALCOTT

FOR THE YEAR ENDING JUNE 30, 1924

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit herewith the customary annual report showing the activities and conditions of the Smithsonian Institution and its branches during the fiscal year ending June 30, 1924. The first 26 pages of the report contain an account of the affairs of the Institution proper, with brief abstracts of the work carried on by the various branches of the Institution, while appendixes 1 to 10 present somewhat more detailed summaries of the operations of the United States National Museum, the National Gallery of Art, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, the United States Regional Bureau of the International Catalogue of Scientific Literature, the Smithsonian Library, and of the publications of the Institution and its branches.

THE SMITHSONIAN INSTITUTION

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust Congress determined that the Federal Government was without authority to administer the trust directly, and therefore constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

The affairs of the Institution are administered by a Board of Regents whose membership consists of "the Vice President, the Chief Justice, three Members of the Senate, and three Members of the House of Representatives, together with six other persons other than Members of Congress, two of whom shall be resident in the City of Washington and the other four shall be inhabitants of some State, but no two of them of the same State." One of the Regents is elected chancellor by the board; in the past the selection has fallen upon the Vice President or the Chief Justice; and a suitable person is chosen by them as secretary of the Institution, who is also secretary of the Board of Regents and the executive officer directly in charge of the Institution's activities.

In regard to the personnel of the board, the following changes occurred during the year: Through his succession to the Presidency on August 2, 1923, owing to the death of President Harding, the Hon. Calvin Coolidge automatically ceased to be a Regent, thus terminating his office as chancellor of the Institution, and to fill the vacancy thus created, the Hon. William H. Taft was elected chancellor of the board on December 13, 1923. Walter H. Newton, Member of the House of Representatives from Minnesota, was appointed a Regent by the Speaker of the House to fill the vacancy caused by the election to the Senate of Frank L. Greene.

The roll of Regents at the close of the fiscal year was as follows: William H. Taft, Chief Justice of the United States, chancellor; Henry Cabot Lodge, Member of the Senate; Medill McCormick, Member of the Senate; A. Owsley Stanley, Member of the Senate; Albert Johnson, Member of the House of Representatives; R. Walton Moore, Member of the House of Representatives; Walter H. Newton, Member of the House of Representatives; George Gray, citizen of Delaware; Charles F. Choate, jr., citizen of Massachusetts; Henry White, citizen of Washington, D. C.; Robert S. Brookings, citizen of Missouri; Irwin B. Laughlin, citizen of Pennsylvania; and Frederic A. Delano, citizen of Washington, D. C.

GENERAL CONSIDERATIONS

In spite of the increasing difficulty in holding its own experienced by the Institution in late years on account of its meager resources and the increasing costs of maintenance, one of its primary functions, the "diffusion of knowledge among men," is carried out with ever-increasing scope, and its contacts with various groups of people are continually growing in number. Of its 11 distinct series of publications, chiefly technical contributions to scientific knowledge though including some more popular papers appealing to the general reader

interested in the progress of science, there are issued every year about 100 volumes and pamphlets, of which there are sent out nearly 150,000 copies. A large proportion of this number go to libraries throughout the world, where they are readily available to the public, and many of its publications are now standard works in various branches of science. Besides this steady flow of publications, the Institution, through the public exhibits of the National Museum, the National Gallery of Art, and the National Zoological Park, imparts an incalculable amount of knowledge on natural history, anthropology, art, and history to the hundreds of thousands of visitors from all parts of the country who come to the Nation's Capital every year. In late years also the value of the arts and industries department of the Museum is becoming more and more appreciated by the public and by industrial organizations, and the exhibits portraying the scope of entire industries are being augmented at an increasing rate by the cooperation of trade associations who assemble these comprehensive exhibits from a number of manufacturers. The auditorium of the National Museum is used every year by a large number of local and national scientific and other societies for the dissemination of useful knowledge through conferences and lectures, and the scientific staffs of the Museum, the Bureau of American Ethnology, and other branches of the Institution contribute their share in the program of the diffusion of knowledge through scientific and semipopular lectures, both officially and unofficially. The archeological excavations conducted in Florida during the past winter by the Chief of the Bureau of American Ethnology were known throughout Florida as the "Smithsonian excavations" and attracted thousands of visitors, to whom Doctor Fewkes lectured several times each week on the prehistoric Indian inhabitants of the region. The latest addition to the Institution's program in the diffusion of knowledge was the inauguration during the year of a series of radio talks on scientific subjects presented in popular form, and the response to these was so widespread that the series will be continued with increased scope during the coming year. This program of dissemination of knowledge in scientific matters is carried on, as stated at the beginning, with the greatest difficulty because of the very limited endowment of the Institution, and were more means at its disposal, the Institution would be enabled to greatly expand its work along these lines, as well as in its other fundamental purpose, the increase of knowledge through scientific research and exploration.

Perhaps the most important development of the year in the Institution's affairs is the promising outlook for a building to house the growing National Gallery of Art. As noted in last year's report, Congress has provided a site in the Smithsonian Park for such

a building and funds were obtained privately for the preparation of plans. Mr. Charles A. Platt was selected as the architect and at the close of the year the plans were well under way. In addition to this, Senator Lodge during the year offered an amendment to the deficiency appropriations bill which would have provided funds for beginning the erection of a building, but the amendment was not accepted. However, these developments indicate an awakening to the realization that America should no longer be practically the only civilized nation on earth without a National Art Gallery, and it is hoped that in the near future funds will be provided for a suitable home for the valuable art collections belonging to the Nation.

FINANCES

The permanent investments of the Institution consist of the following:

Deposited in the Treasury of the United States $1,000,000.00

CONSOLIDATED FUND

Miscellaneous securities, etc., either purchased or acquired by gift; cost or value at date acquired 194,826.50

Charles D. and Mary Vaux Walcott research fund, stock (gift) value 11,520.00

The sums invested for each specific fund, or securities, etc., acquired by gift are described as follows:

Fund	United States Treasury	Consolidated fund	Walcott research fund	Total
Avery fund	$14,000.00	$29,557.52		$43,557.52
Virginia Purdy Bacon fund		50,362.34		50,362.34
Lucy H. Baird fund		1,349.58		1,349.58
Chamberlain fund		34,952.27		34,952.27
Habel fund	500.00			500.00
Hamilton fund	2,509.00	500.00		3,000.00
Caroline Henry fund		1,074.00		1,074.00
Hodgkins general fund	116,000.00	37,226.57		153,226.57
Hodgkins specific fund	100,000.00			100,000.00
Bruce Hughes fund		12,013.62		12,013.62
Morris Loeb fund		7,390.00		7,390.00
Lucy T. and George W. Poore fund	26,670.00	13,238.86		39,908.86
Addison T. Reid fund	11,000.00	4,919.00		15,919.00
Rhees fund	590.00	268.00		858.00
George H. Sanford fund	1,100.00	506.00		1,606.00
Smithson fund	727,640.00	1,468.74		729,108.74
Charles D. and Mary Vaux Walcott research fund			$11,520.00	11,520.00
Total	1,000,000.00	194,826.50	11,520.00	1,206,346.50

Dr. William L. Abbott has continued his contributions during the year for researches in natural history and collection of specimens in China.

Further generous contributions have been made by Mr. John A. Roebling for researches in astrophysics, providing for aiding the

solar observing stations in Chile and the United States, for publication of scientific papers, for purchase of instruments, and for making meteorological investigations elsewhere.

Mr. Washington A. Roebling has made a generous donation for the purchase of minerals.

The National Academy of Sciences has given the sum of $1,500 for researches in paleontology.

The Institution is also indebted to the Research Corporation for $1,250 for research work.

Freer Gallery of Art.—In compliance with the instructions of the Board of Regents, a sinking fund for the investment of surplus income from the Freer bequest has been created. The amount paid into this fund during the year was $138,688.75. The invested funds of the Freer bequest are classified as follows:

Curator's fund	$278,825.50
Court and grounds fund	278,825.50
Court and grounds, maintenance fund	69,683.75
Residuary legacy	2,676,232.75
Sinking fund	138,688.75
Total	3,442,256.25

The practice of depositing on time, in local trust companies and banks, such revenues as may be spared temporarily has been continued during the past year, and interest on these deposits has amounted to $1,014.59. The income during the year for current expenses, consisting of interest on permanent investments and other miscellaneous sources, including cash balance at the beginning of the year, amounted to $72,558.59. Revenues and principal of funds for specific purposes, except the Freer bequest, amounted to $91,919.99. Revenues on account of Freer bequest amounted to $234,446.50. Cash recalled from the time deposits, $34,000; aggregating a total of $432,925.08.

The disbursements, described more fully in the annual report of the executive committee, were classed as follows: General objects of the Institution, $64,960.03; for specific purposes (except the Freer bequest), $58,501.72; temporary advances for field expenses, etc., in excess of repayments, $4,130.12; expenditures pertaining to the Charles L. Freer bequest, $291,768.05; and cash balance on hand June 30, 1924, $13,565.16.

The following appropriations were intrusted by Congress to the care of the Smithsonian Institution for the fiscal year 1924:

International exchanges	$43,000
American ethnology	44,000
International Catalogue of Scientific Literature	7,500
Astrophysical Observatory	15,500

National Museum:		
Furniture and fixtures	$20,000	
Heating and lighting	70,000	
Preservation of collections	312,500	
Building repairs	10,000	
Books	2,000	
Postage	500	
		415,000
National Gallery of Art		16,000
National Zoological Park		125,000
Increase of compensation		112,704
Printing and binding		77,400
Total		856,104

RESEARCHES AND EXPLORATIONS

Every year the Institution engages, so far as its limited means will permit, in explorations and field work, and a few of these expeditions will be mentioned here briefly to indicate the nature of the work accomplished. A number of other expeditions and researches in various fields of science are described in the appendixes on the National Museum, the Bureau of American Ethnology, the Astrophysical Observatory, and the Freer Gallery of Art. In a few cases, the entire expedition is financed and managed by the Institution, but the small amount of income remaining each year, after the administrative costs of carrying on the work of the Institution are met, is soon exhausted, and thereafter it is only possible to cooperate in various ways in expeditions financed by other scientific institutions.

GEOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES

During the summer and early fall of 1923, your Secretary continued his geological field work in the Canadian Rockies of Alberta and British Columbia. His main objective was to secure data on the pre-Devonian strata from the Clearwater River southeast to the Bow Valley and along the eastern side of the Columbia River Valley.

It was found that the Mons formation which was discovered on the headwaters of the Saskatchewan River at Glacier Lake, extended southwesterly on the western side of the Continental Divide in British Columbia to the southern end of the Stanford Range between the Kootenay River and Columbia Lake, which is at the head of the Great Columbia River, which here flows northwesterly in what is known as the Rocky Mountain Trench. The valley of this latter river was found to be largely underlain by the limestones and shales of the Mons formation of the Ozarkian system, and the strata have been upturned, faulted, and folded prior to the great pre-Glacial

period of erosion that cut out the Rocky Mountain Trench. On the eastern side of this valley, the Mons formation is more than 3,800 feet in thickness in the Beaverfoot-Brisco-Stanford Range, and contains four well-developed fossil faunas which show it to lie between the Upper Cambrian and the Ordovician systems of this and other parts of the continent. Near the head of the Sinclair Canyon there was discovered a great development of the Lower Ordovician, and at several localities cliffs of massive Upper Cambrian limestones were recognized beneath the Mons formation.

This whole region is ideal for geological field work, as the numerous canyons and ridges expose many of the formations from base to summit. On the whole, the season was a successful one for its geological results.

EXPEDITION TO DINOSAUR NATIONAL MONUMENT, UTAH

In May, 1923, Mr. C. W. Gilmore, curator of vertebrate paleontology, National Museum, was detailed to take charge of an expedition to the Dinosaur National Monument in northeastern Utah for the purpose of securing for exhibition in the Museum a mountable skeleton of the large sauropodous dinosaur, *Diplodocus*. The fossil deposit in this region was discovered in 1909 by Mr. Earl Douglass, and has been worked continuously since that time by the Carnegie Museum of Pittsburgh. By 1922, the Carnegie Museum had secured sufficient material for their purposes, and the Institution was notified of their intention to cease operations, leaving uncovered two partially articulated specimens of *Diplodocus*, a mountable skeleton of which has long been desired by the National Museum. Mr. Gilmore arrived at the fossil quarry on May 15, and a preliminary survey showed that one of the two skeletons would form the basis of a mountable specimen while the preserved parts of the other would serve admirably to replace the missing bones of the first. Regular work in the quarry began on May 24 and continued until August 8. Mr. Gilmore employed three men with experience in this field, and was assisted after June 5 by Mr. Norman H. Boss, of the Museum's paleontological force. Regarding the difficulties involved, Mr. Gilmore says:

> The work of quarrying these often fragile bones from the ledge of rock without doing irreparable damage is a slow and tedious operation, involving the skill of both the stone cutter and the miner. Further difficulty is encountered in handling by primitive methods the immense blocks of rock inclosing the bones, with the subsequent arduous work of boxing and transportation. The largest block quarried, containing the sacrum with attached hip bones, weighed nearly 6,000 pounds when ready for shipment. The transportation of the boxes to the railroad involved a haul by teams of 150 miles across country and over a range of mountains 9,100 feet above sea level. However, 34 large boxes having a combined weight of over 25 tons were safely transported.

As a result of this expedition, enough material was secured for a good skeletal mount of *Diplodocus* which, it is estimated, will exceed 80 feet in length with a height at the hips of 14 feet.

BIOLOGICAL EXPLORATIONS IN THE YANG-TZE VALLEY, CHINA

Through the continued generosity of Dr. W. L. Abbott, Mr. Charles M. Hoy sailed for China toward the close of 1922 to collect vertebrates for the Institution in the Yang-Tze Valley region. His first collecting was done in the Yochow district, where he obtained a total of 169 mammals and 84 birds. At the beginning of the fiscal year just past, Hoy left for a trip through Hunan and Kiangsi, in the course of which many interesting specimens were obtained. From Kuling, Kiangsi, a letter was received from Hoy, describing a series of misfortunes, as follows:

> The day after writing my last letter to you, from Iningchow [never received], I had a bad fall and badly wrenched my back. For about a week I was scarcely able to crawl about. Just when my back was getting so I could straighten up I had another accident and shot myself through the left leg with the Colt 45 automatic. The accident was due to a "hang fire." The gun did not go off when the hammer struck and so I lowered the gun to eject the shell when the shell exploded. The bullet struck me on the inside of the leg 4 inches above the ankle bone. * * * The wound is healing nicely, but the doctor says that it may be several months before I get full use of my foot and that I will most likely have a slight permanent limp. However, I am hoping that it won't interfere with my collecting, but even if I won't be able to do much walking myself I have one man who is a crack shot with the shotgun and another that is fair with the rifle, so I ought to be able to get specimens anyhow. My trip down from Iningchow was rather uneventful except for the above accidents. We were under military guard all the way from there to Kuikiang. The country, it seems, is full of disbanded Northern soldiers who have driven out the natives and occupied their farms. Consequently it is dangerous for even natives to travel through that region. The final explanation given me, as to the reason of the escort, was that it was feared that my guns and ammunition might fall into their hands. We were fired on once, in the night, but aside from a lot of shouting and that one shot, nothing happened. We could never learn who fired the shot, but the way things turned out I am convinced that we were mistaken for bandits and the shot was fired to scare us off. Owing to the accidents, I have not been able to secure any specimens since the writing of my last letter. My outfit has not yet arrived owing to the heavy rains, but as soon as it gets here I plan to send my men out collecting so I will be able to get specimens notwithstanding the fact that I am confined to the house.

The gunshot wound was apparently healing, but while Hoy was still confined to the house he developed a severe case of appendicitis, necessitating an immediate operation, from which he never recovered.

BOTANICAL EXPLORATION IN PANAMA AND CENTRAL AMERICA

Dr. William R. Maxon, associate curator of plants in the National Museum, was detailed in May, 1923, to accompany an expedition

from the Department of Agriculture to Panama and Central America. Unfortunately rains interfered seriously with field work in both Panama and Nicaragua, but in spite of this handicap, a general botanical collection of about 4,500 specimens was made, about equally divided among Panama, Nicaragua, and Costa Rica. In his report on the expedition, Doctor Maxon says:

> Aside from two days given to collecting in the interesting Juan Diaz region, east of Panama City, work in Panama was mostly confined to the Canal Zone, being conducted chiefly from headquarters on the Pacific side, at Balboa, with the courteous assistance of the Panama Canal authorities. Of particular interest were trips to Barro Colorado, a large wooded island in Gatun Lake opposite Frijoles, recently set aside as a wild reserve upon representation of the Institute for Research in Tropical America; the virgin forest region at the headwaters of the Rio Chinilla, above Monte Lirio; and the Fort Sherman Military Reservation, which includes the famous old Spanish stronghold, Fort San Lorenzo, at the mouth of the Chagres. All these localities are forested and are rich in palms, and special attention was directed to obtaining material in this difficult group. With the steady clearing of leased land for planting bananas the original forest in the Canal Zone is rapidly disappearing, and with it its characteristic palm associations. * * *
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> About three weeks were spent in Nicaragua, wholly in the region west of Lake Nicaragua and mainly working from Managua, the capital, which lies picturesquely at a new elevation 90 miles inland from the Pacific coast, flanked by numerous volcanoes. Except for the volcanoes and the low range called the Sierra, given over to coffee production, western Nicaragua is low and almost entirely cleared of forest. Cane and grazing are the main industries. The soil is largely a rich black loam of volcanic origin, and supports a luxuriant growth of tall grasses, the arborescent vegetation being mainly confined to roadsides and abandoned "potrero." The most interesting trips were to the region of Casa Colorado in the Sierra, and to Mombacho and Santiago volcanoes. The material collected indicates a rich flora for the higher mountain slopes, one that would amply repay extended exploration.
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> From Corinto Doctor Maxon proceeded by steamer to Puntarenas, the Pacific port of Costa Rica. The ascent by rail from this port in the semiarid coastal plain to the capital, San José, lying at an altitude of 1,140 meters in the cool *meseta central*, is through a region remarkably diverse as to physiography. From San José three principal trips were made: First, to La Palma, a classical botanical locality on the cloud-drenched southwestern slopes of Irazú volcano; next to Santa Clara in the mountains a few leagues south of Cartago; then to Vara Blanca lying high up in an almost unexplored region between the volcanoes Poás and Barba. Special attention was here given to ferns and orchids, both groups being extremely abundant both as to species and individuals, and many new and interesting species in these and other groups were collected.

STUDIES ON EARLY MAN IN EUROPE

During the summer and early fall of 1923, Dr. Aleš Hrdlička, curator of physical anthropology, National Museum, revisited the important sites of early man in western and central Europe, as well as the institutions in which are preserved the skeletal remains of

ancient man and the fossil European apes. During the trip Doctor Hrdlička acted as director of the American School in France for Prehistoric Studies, and was accompanied by a number of American graduate students. One of the principal objects of the trip was to secure accurate measurements of the teeth, particularly the lower molars, of the larger fossil apes and early man by one observer, by a strictly defined method, and with accurate instruments. Another object was to take photographs of the various sites of early man of which good photographs were not available.

The trip included visits to various regions in England, Holland, Belgium, France, Germany, Bohemia, Austria, and Croatia. In these countries practically all of the important sites were visited and as far as possible the skeletal remains of early man and the fossil apes in museums along the route were examined and measured. In many cases assistance was given by prominent anthropologists connected with these institutions in giving first-hand reviews of the knowledge concerning the specimens and sites, and sometimes in personal conduct to the sites themselves. In Holland Doctor Hrdlička had the unique privilege of visiting Prof. Eugene Dubois, of Haarlem, and seeing the famous remains of the Pithecanthropus as well as the other Java remains in his possession. Regarding the Pithecanthropus remains, Doctor Hrdlička says:

> The remains of, or those attributed to, the Pithecanthropus consist of the now thoroughly cleansed skull-cap, a femur and three teeth, two molars and one premolar. Besides these there is from another locality a piece of a strange primitive lower jaw, and also two skulls with many parts of the skeletons of a later, though yet rather primitive, type of man from consolidated calcareous deposits in still another part of the island.
>
> The examination of the originals belonging to the Pithecanthropus find was in many respects a revelation. It was seen that none of the casts now in various institutions are accurate, and that the same is true of the so far published illustrations, above all those of the teeth and femur. The originals are even more important than held hitherto. The new brain cast shows an organ very close to human. The femur is without question human. When the detailed study of all these specimens is published, which Doctor Dubois expects to occur before the end of the winter, the specimens, though all controversial points may not be settled, will assume even a weightier place in science than they have had up to the present.
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> The trip resulted in an overwhelming sense of the greatness and scientific importance of the field of early man in western and central Europe and in a keen appreciation of the opportunities for cooperation in this field by American students.

SMITHSONIAN SERIES OF RADIO TALKS

Beginning on October 19, 1923, arrangements were made with radio station WRC, of the Radio Corporation of America, to broadcast a series of talks on the Institution and its branches. These

were continued until November 16, with such success that in the spring the conclusion was reached that there would be mutual advantage to the Institution and to station WRC in giving a series of talks on scientific subjects. Accordingly there was established a regular Smithsonian period every Wednesday at 6.15 p. m., and the series was opened on April 9 by a talk on "The giants of the animal world," by Mr. Austin H. Clark. This was followed by 10 others, the last one being given on June 18, when the program was discontinued for the summer months.

This new means of carrying out the Institution's function of the diffusion of knowledge appears to be highly effective, as indicated by the number of responses to the talks received at the Institution and at the broadcasting station. The direction of the entire program was placed under Mr. Austin H. Clark, of the National Museum, who secured the cooperation not only of the members of the staff of the Institution and its branches but also of the Carnegie Institution of Washington and of the various scientific bureaus of the Government whose work is complementary to that of the Institution. Altogether there were given during the year 18 talks in the Smithsonian series, as follows:

The Smithsonian Institution, by Austin H. Clark.

The Work of the Smithsonian Observatory, by C. G. Abbot.

The Bureau of Ethnology: What It Is and What It Does, by J. Walter Fewkes.

Department of Arts and Industries of the United States National Museum, by Carl W. Mitman.

The Historical Collections of the Smithsonian Institution, United States National Museum, by Theodore T. Belote.

The National Gallery of Art, by W. H. Holmes.

The National Herbarium, by F. V. Coville.

The Giants of the Animal World, by Austin H. Clark.

Little Folks in Greenland, by Elisabeth Deichmann.

The National Zoological Park, under the direction of the Smithsonian Institution, by N. Hollister.

Useful Plants from America, by F. L. Lewton.

Shooting Stars and What They Are, by George P. Merrill.

Animal Terrors of Past Ages—Dinosaurs, by Charles W. Gilmore.

Surveying the Ocean with the Non-Magnetic Yacht Carnegie, by J. P. Ault, of the Carnegie Institution.

Program of native Indian music arranged by Miss Frances Densmore.

Large Game Animals of North America, by E. W. Nelson, Chief of the Bureau of Biological Survey.

Flying Animals, by Austin H. Clark.

Atmospheric Electricity, by D. J. Mauchly, of the Carnegie Institution.

The interest shown in these informative radio talks on scientific matters and the vast audience which it is possible to reach through the microphone make it apparent that this is destined to become a

most important phase of the Institution's work in diffusing knowledge, and it is intended to renew the series with increased scope in the fall.

ASSISTANCE TO JAPANESE LIBRARIES DESTROYED DURING THE RECENT EARTHQUAKE

The recent disastrous earthquake in Japan destroyed large collections of books in many of the Japanese libraries, including the entire collection of 700,000 volumes in the library of the Imperial University of Tokyo. During the year an appeal was received in this country from the Japanese Association of the League of Nations for books to replenish these unfortunate libraries, especially those of universities and colleges. The Institution made up as nearly as possible complete sets of its own publications and forwarded them to a number of the Japanese libraries, the volumes and pamphlets thus sent totaling several hundred. In addition, the International Exchange Service of the Institution served as a central forwarding agency for the other American institutions desiring to contribute their publications, and during the year several large consignments containing many thousands of publications were transmitted to Japan.

COOPERATION WITH ORGANIZATIONS MEETING IN WASHINGTON

There has been during the year an unusually large number of meetings in Washington of scientific or other organizations whose work has been in some way related to that of the Smithsonian. In providing an auditorium in the Museum for these meetings, and through the assistance given in various ways by the scientific and administrative staff, the Institution has been able to render a real service in promoting scientific work and discussion. To illustrate the appreciation of this service by organizations taking advantage of these facilities, there may be mentioned three important meetings held during the year. The American Association of Museums held its nineteenth annual meeting in Washington May 10–13, most of the sessions being held at the National Museum. After the meeting the secretary of the association wrote to the Institution in part as follows:

> The success of the nineteenth annual meeting of the American Association of Museums was due in considerable part to the hospitality of the Smithsonian Institution and the friendly help of many individuals on its staff.

At the close of the first National Conference on Outdoor Recreation, held in Washington in June, the following resolutions were passed:

Whereas the success of this first National Conference on Outdoor Recreation is due in large measure to the very fine services and facilities made available by the officers of the Smithsonian Institution and the National Museum, who have been untiring in their efforts to promote the comfort and convenience of the delegates to the conference: Therefore be it

Resolved, That the conference hereby expresses its sincere appreciation of the spirit of cordial hospitality displayed by the officers and employees of these great scientific and educational agencies and requests its executive chairman to so advise Dr. Charles D. Walcott, Secretary of the Smithsonian Institution, and his official associates.

The annual meeting of the National Academy of Sciences, which has for many years been held in the National Museum, was held this year for the first time in the academy's new building. The following resolution passed during the sessions expresses appreciation of the services which the Institution has been able to render to the academy in the past:

Resolved, That on the occasion of the removal of its offices from the Smithsonian Institution to its new building, the National Academy of Sciences gratefully expresses its obligations to the Secretary and the Board of Regents of the Smithsonian Institution for the courtesies extended for over half a century through the housing and care of the academy records and library, through its cooperation in the conduct of academy business, and through its effective aid in promoting the objects of the academy;

And that the academy expressly acknowledges its high esteem and thanks to the Secretary of the Smithsonian Institution, Charles Doolittle Walcott, for his personal interest in the welfare of the academy, his unfailing interest in and attention to the work of the academy in the advancement of science, and his distinguished services as treasurer, vice president, acting president, president, and member of the council and committees, both official and unofficial, in its behalf.

PUBLICATIONS

There were issued during the year by the Institution and its branches a total of 70 volumes and pamphlets, of which 142,385 copies were distributed, including 407 volumes and separates of the Smithsonian Contributions to Knowledge, 25,937 volumes and separates of the Smithsonian Miscellaneous Collections, 19,085 volumes and separates of the Smithsonian Annual Reports, 3,743 Smithsonian special publications, 78,734 volumes and separates of the various series of the National Museum publications, 13,974 publications of the Bureau of American Ethnology, 78 publications of the National Gallery of Art, 65 volumes of the Annals of the Astrophysical Observatory, 35 reports on the Harriman Alaska Expedition, and 1,275 reports of the American Historical Association.

The publications of the Institution, now issued in 11 distinct series, are its principal means of carrying out a part of its stated purpose, "the diffusion of knowledge." There is a widespread and growing demand for its publications, not only from specialists for

the more technical series, but also from the general public, among whom the importance of scientific matters is coming to be more and more realized. This popular demand is chiefly for the Smithsonian Annual Reports, which contain a general appendix consisting of series of specially selected articles presenting in readable form progress and interesting developments in all branches of science. Unfortunately, owing to the rush of work at the Government Printing Office both during the war and since, these volumes have fallen behind date, until now they are issued over two years late. However, for the coming fiscal year, Congress has allotted an additional amount to enable the Institution to catch up with these reports by issuing two in one year, and it is hoped that within a year or two they will again appear more nearly on time.

The various publications of the National Museum and of the Bureau of American Ethnology are given in detail in the report on publications appended hereto.

In the series of Smithsonian Miscellaneous Collections 13 papers were issued during the year, among which may be mentioned two papers by your secretary on the results of his geological field work in the Canadian Rockies; an illustrated pamphlet on the History of Electric Light, by Henry Schroeder, of the General Electric Co.; a paper on the Telescoping of the Cetacean Skull, by Gerrit S. Miller, jr., of the National Museum; and a second paper by Dr. J. Walter Fewkes describing and figuring the beautiful designs on prehistoric Indian pottery from the Mimbres Valley, N. Mex.

Allotments for printing.—The congressional allotments for the printing of the Smithsonian reports and the various publications of the branches of the Institution were practically used up at the close of the year. The appropriation for the Institution and its branches for the coming year ending June 30, 1925, totals $90,000, allotted as follows:

Annual Report of the Board of Regents of the Smithsonian Institution	$22,600
National Museum	37,500
Bureau of American Ethnology	21,000
National Gallery of Art	1,000
International Exchanges	200
International Catalogue of Scientific Literature	100
National Zoological Park	300
Astrophysical Observatory	300
Annual Report of the American Historical Association	7,000

Committee on printing and publication.—The Smithsonian advisory committee on printing and publication considers all manuscripts offered for publication by the Institution and its branches and makes recommendations thereon to your secretary. It also considers matters of publication policy and means of effecting econ-

omies in the Institution's printing and binding. During the year nine meetings were held and 100 manuscripts acted upon. The membership of the committee is as follows: Dr. Leonhard Stejneger, head curator of biology, National Museum, chairman; Dr. George P. Merrill, head curator of geology, National Museum; Dr. J. Walter Fewkes, chief, Bureau of American Ethnology; Mr. N. Hollister, superintendent, National Zoological Park; and Mr. W. P. True, editor of the Smithsonian Institution, secretary. Toward the close of the year there were added to the membership of the committee Dr. Marcus Benjamin, editor of the National Museum, and Mr. Stanley Searles, editor of the Bureau of American Ethnology.

LIBRARY

The service of the libraries administered under the Smithsonian Institution has been continued, although with increasing difficulty owing to the need for more assistants. Mr. Paul Brockett resigned as assistant librarian, after 37 years with the Smithsonian Institution, in order to assume charge of the new building of the National Academy of Sciences as assistant secretary and librarian.

The additions to the libraries reached a total of 12,249, as compared with 10,938 the past year. The number of loans was 13,326, as compared with 12,076 the past year, exclusive of books lent from the Smithsonian deposit in the Library of Congress. Efforts to secure missing parts for including in incomplete sets resulted in the receipt of 1,786. Owing to the lack of sufficient clerical help, it has not been possible to have typed for the general library catalogue the catalogue cards of special collections that have been prepared during the year. Consequently the number of volumes catalogued for the general catalogue dropped from 6,341 to 5,348.

Probably the most important addition of the year was the Edgar E. Teller collection presented by Mrs. Teller to the library of the United States National Museum. The catalogue of the European Historical Series of the Watts de Peyster collection is approaching completion.

NATIONAL MUSEUM

Since 1916 the collections in the care of the Museum have been increased by two and one-fourth million specimens, and its exhibition space has been enlarged by the addition of the Aircraft Building. Unfortunately, however, the appropriations have not kept pace with this rapid development, and it is now only with the greatest care and economy that the actual work of the safe-keeping of the collections and their classification and exhibition is carried on. There is practically nothing left to care for the normal expansion

of the Museum's work and for increasing its usefulness to the people of the country. The Museum, with its vast collections, serves the public not as it would and could but as its limited financial resources permit. One forward step has been made, however, in the reclassification of salaries which becomes effective on July 1, 1924, and as a whole the scientific force of the Museum is at last to receive adequate compensation.

The outstanding feature of the year was the gift to the Nation for exhibition in the National Museum of a complete American colonial room, presented by Mrs. Gertrude D. Ritter, of Washington, D. C. This notable gift includes wall paneling from the old Bliss homestead at Springfield, Mass., and a remarkable collection of furniture, china, glassware, pewter, pictures, and textiles belonging to the same period of early American history. The room is set up and arranged in one of the Museum rooms exactly as it would have appeared in a colonial home of the period of about 1750.

A program of intensive work on the development of the Loeb collection of chemical types was made possible this year through the accrued interest on the Loeb fund. A curator of the collection was appointed and the advisory committee reorganized, and it is expected that in a year or two the value of such a type series of chemicals will be amply shown.

The Museum received during the year 362,942 specimens, a notable increase over last year in numbers and also in scientific value. Over 8,000 duplicate specimens classified and labeled were distributed for educational purposes to schools and colleges. A somewhat detailed account of the accessions in the various departments of the Museum is given in the report of the administrative assistant in charge, and only a few of the more notable acquisitions will be mentioned here. In anthropology a noteworthy collection of ethnological material from the Philippines, made by the late Capt. E. Y. Miller, was presented by Mrs. Florence G. Miller, and a number of specimens representing several Indian tribes of South America was the gift of Dr. D. S. Bullock. A valuable series of unique ancient earthenware bowls from the Mimbres Valley, N. Mex., was presented by the Bureau of American Ethnology. A series of prehistoric antiquities from ancient sites in France, Belgium, and Germany was added by Dr. Aleš Hrdlička as the result of his recent trip to Europe.

The collections received in biology greatly surpass those of recent years both numerically and in scientific importance, the latter point being emphasized by the addition of a large number of species and genera new to the Museum, many gaps in the collections having been filled. The outstanding accession of the year is the gift by Dr.

J. M. Aldrich, associate curator of insects, of his collection of 45,000 specimens of dipterous flies, the result of his life's collecting and study. Considerable collections were received from Rev. D. C. Graham, made during his explorations in the Province of Szechwan, China. Dr. W. L. Abbott secured a large number of plants, reptiles, and amphibians during an expedition to Santo Domingo. The National Herbarium was greatly enriched by three expeditions to tropical America, that of Dr. A. S. Hitchcock to Panama, Ecuador, Peru, and Bolivia; of Paul C. Standley to the Canal Zone and Costa Rica; and of Dr. William R. Maxon to Panama, Costa Rica, and Nicaragua. The research work of the staff of the department of biology has been continued whenever time could be spared from the necessary work of caring for the increasing collections, but the divisions are greatly undermanned and much more scientific work would be accomplished if more assistants were available.

The department of geology received a large amount of material of unusual value for both exhibition and study purposes, the most noteworthy accessions being the large sauropodous dinosaur from the Dinosaur National Monument, Utah, and the Edgar E. Teller and George M. Austin collections of fossils, which together comprise at least 125,000 specimens. The economic collections have been increased by the addition of a number of ores and by a series of diamond-bearing rocks from Arkansas. Meteoric irons from New Mexico, Kansas, Chile, Spain, and Australia added new material to the meteorite collection. The mineral collections received a number of specimens chiefly through the generosity of Col. Washington A. Roebling, and several cut gems were added to the Isaac Lea collection. Expansion of the study series and research work occupied much of the time of the curators and their assistants.

The divisions of mineral and mechanical technology received many interesting additions, including two automobiles presented by the Cadillac Motor Co., one made in 1903 and the other in 1923, the latter being cut away in cross section to show the working parts. Another valuable accession was a complete working unit of a Strowger automatic telephone system equipped with three telephones which can be operated by the visitor, thus enabling him to observe the functioning of the apparatus. The division of textiles, including also wood technology, organic chemistry, foods, and medicine, received over 3,300 specimens during the year, including large series of industrial specimens illustrating every branch of rubber manufacture, the manufacture of leather and shoes, and the preparation and dyeing of seal, muskrat, and rabbit skins. There were also accessioned many chemical materials used in various industries, a number of interesting textiles, and material of value to be added

to the exhibitions in the division of medicine. The division of graphic arts received numerous additions pertaining to the history and development of the printing art and held a number of successful exhibitions of prints, etchings, lithographs, and photographs. In the division of history the most notable addition was the American colonial room presented by Mrs. Gertrude D. Ritter, mentioned previously in this summary. The division also received a gown worn by Mrs. Warren G. Harding and another worn by Mrs. Benjamin Harrison to be added to the collection of costumes of ladies of the White House in which so much popular interest is shown.

The Museum participated in a number of field expeditions which have resulted in greatly increasing the collections in the various departments. These are described in the report on the Museum appended hereto. The auditorium was used by a large number of scientific and other societies and organizations for lectures and meetings. Visitors to the Natural History Building during the year totaled 540,776; to the Arts and Industries Building, 290,012; to the Aircraft Building, 43,534; and to the Museum exhibits in the Smithsonian Building, 104,601. Eight volumes and 44 separates were published by the Museum during the year, and of these 78,734 copies were distributed.

NATIONAL GALLERY OF ART

The year has witnessed substantial advance in the work of the gallery, and a number of important art works were received notwithstanding the fact that there is no longer suitable space available for the display of additional exhibits. Constant effort has been made during the year to impress upon the country the urgent need of a National Gallery Building, and gratifying assurance of the awakening of public interest in national art is given by the introduction in the Senate by Senator Lodge of an amendment to the deficiency appropriations bill to provide for commencing the erection of a suitable building for the gallery. Although this amendment did not pass at the last session of Congress, it is hoped that favorable action will soon be taken. It will be recalled from last year's report that Congress has provided a site in the Smithsonian grounds for such a building and that funds were raised privately for the preparation of plans. At the close of the year Mr. Charles A. Platt, the architect selected, had the plans well under way.

The annual meeting of the National Gallery Commission was held on December 11 and a number of important topics were considered, including the problem of securing a National Gallery Building, a recommendation that a division of historical architecture be included in the National Gallery of Art, and the selection of an architect for

the proposed building. Mr. Gari Melchers was selected to succeed Mr. Daniel C. French, who had resigned as chairman of the commission.

Permanent accessions to the gallery for the year were limited to about 10 paintings, but Mrs. Ralph Cross Johnson deposited a collection of 11 early Christian paintings by Italian, Dutch, Flemish, and Spanish masters, and has indicated her intention of making the "deposit" a permanent addition to the gallery. A number of loans were accepted during the year, and the gallery in turn loaned a number of paintings to accredited art institutions. Three special exhibitions were held in the gallery during the year, and the World War portrait collection was installed in an improvised gallery on the second floor of the Natural History Building of the National Museum, which proved to be quite satisfactory for their exhibition.

FREER GALLERY OF ART

Work completed during the year includes the examination, classification, and cataloguing of Chinese and Japanese stone sculptures and paintings, and much additional work has been accomplished in the preservation, framing, lettering, and mounting of paintings, etchings, and lithographs. Identification photographs have been made of many objects in the collection to provide ready reference and to save handling of the collections. A special exhibition of Whistler etchings, dry points, and lithographs was held in four of the galleries during January and February. Fourteen hundred gallery books describing the objects on exhibition have been prepared, and there have also been issued a Synopsis of History for the use of students and a third printing of the pamphlet giving general information about the gallery and collections.

Additions to the collections by purchase included Chinese bronzes, Indian paintings, Persian paintings, and Chinese sculptures, and the library was increased by the addition of a number of books and pamphlets in various Asiatic and European languages. Several cases, picture frames, and other necessary articles of equipment were constructed in the gallery workshop.

The total attendance for the year was 111,942, including 482 visitors who came to work in the study rooms or to examine objects not on exhibition. The auditorium of the gallery was used in February by the Library of Congress for the presentation of three recitals of chamber music, and in April, Prof. Paul Pelliot, of the Collège de France, gave an illustrated lecture on "Chinese bronzes, jades, and sculptures."

The archeological expedition to China under the joint auspices of the gallery and the Museum of Fine Arts, Boston, has carried on

fruitful investigations in various localities in China, latterly at Yü-ho Chên, in Honan, where some burials of the Han dynasty have been thoroughly investigated with gratifying results. Even more important is the cooperative agreement with regard to archeological investigation established between the gallery and the Chinese authorities, which was confirmed by the unsolicited appointment of Mr. Bishop as Honorary Adviser in Archeology to the Historical Department of the Chinese Government. This is the first definite effort of the kind to bring Chinese archeologists and officials together in a beneficial relationship with western archeologists and museums, which it is hoped will provide a basis for more enlightened scholarship and gradually supplant the ruthless and unscientific collecting of Chinese antiquities on a commercial scale as hitherto allowed.

BUREAU OF AMERICAN ETHNOLOGY

The aim of the Bureau of American Ethnology is to discover and disseminate correct ideas of the Indian as a race, that our people may better understand and appreciate his history, language, sociology, music, religion, and various arts and industries. The sources of this information are from year to year becoming fewer and fewer as the customs indigenous to America are lost in the settlement of the former homes of the Indians by the white race. It is therefore imperative that intensive work be carried on by the staff of the bureau to record accurately as much as possible of this material from the Indians themselves before it is too late.

The greatly increased number of visitors to the national parks and Indian reservations of the Western States, due to the present popularity of automobile touring, has led to a desire on the part of the general public for more information on the history and customs of the Indians, and urgent calls from universities and other institutions for advice and assistance in local problems relating to the Indians have been more numerous than ever before. The bureau's most effective means of supplying this information and answering these calls is its unique series of publications on every phase of Indian life and culture. With the greatly increased cost of printing and the very limited funds for the purpose placed at the disposal of the bureau, there has resulted a very unfortunate congestion of manuscripts awaiting publication. It is usually two or three years after a report is handed in by a member of the staff before it can even be sent to the printer, which not only results in difficulty in supplying the requests of the public but is very discouraging to the scientific staff who are carrying on this work.

A large proportion of the time of the chief of the bureau is devoted to administrative work, but opportunity was found to carry on

an archeological expedition to southwestern Florida, where but little work of this character has previously been done. With the aid of Mr. E. M. Elliott and his associates, of St. Petersburg, Doctor Fewkes began the excavation of certain large shell mounds on Weeden Island near St. Petersburg. One of the largest mounds proved to be a cemetery, and from November until March about one-half of it was excavated. A large collection of aboriginal objects and skeletons was made, which gives evidence of two distinct cultures, one above the other. The lower contained crude pottery and a few implements mostly of shell bearing considerable likeness to the so-called Archaic Antillean culture of Cuba. The upper layer gave very fine specimens of decorated pottery and other objects which show close relationship to the Indian culture of Georgia, indicating a southward extension of population possibly allied to the Muskhogean into the Florida Peninsula. This field work of the bureau in Florida inaugurates a plan of cooperation of members of the staff and others to determine the boundaries and extension of the great Muskhogean culture of the Gulf States, the object being to obtain information on the relationship of the mounds of our southern States to those of the Huastecs on the Gulf coast of Mexico.

Dr. John R. Swanton completed the translation of stories from his Koasati, Alabama, Hitchiti, and Creek texts; edited a manuscript on Indian trails by the late W. E. Myer; and began the preparation of a card index of all words in the Timucua language in the religious works of the Franciscan missionaries Pareja and Movilla, nearly all that is left to us of this old Florida tongue. Dr. Truman Michelson carried on ethnological studies among the Indians of Labrador. From his work it appears that the language of the Nascopi and Davis Inlet Indians is the same, and merely a Montagnais dialect rather than a distinct language. It may be noted that the folklore of the Indians of Labrador contains more elements occurring among Central Algonquians than has been suspected. At the close of this work, he continued his researches of former years among the Fox Indians at Tama, Iowa, devoting especial attention to the ceremonial runners of these Indians.

Mr. J. P. Harrington took charge of the exploration of the Burton Mound at Santa Barbara, Calif., under a joint arrangement with the Museum of the American Indian, Heye Foundation. Many facts of interest for the prehistory of the Santa Barbara Indians and the early culture of the Pacific coast in general were recorded, and a great number of skeletons, utensils, weapons, and trinkets were secured. Mr. J. N. B. Hewitt was engaged during the greater part of the year in working up the material gathered in former years relating to the League or Confederation of the Five Iroquois Tribes or Nations. In

June he visited the Six Nations of Iroquois near Brantford, Ontario, Canada, and the Onondaga, Tonowanda, and Tuscarora in New York State for the purpose of securing certain data regarding the Condolence and Installation Council.

Mr. Francis La Flesche devoted his time to the assembly of his notes on the child-naming rites and ceremonies of the Osage Indians. Mr. La Flesche has succeeded in securing two of the remaining versions of these rites which are now practically obsolete, and these will form the two parts of a publication on the subject, now nearing completion. Mr. W. E. Myer on his return from field work in Tennessee began preparation of a report on the remains of the great prehistoric Indian settlement known as Great Mound Group in Cheatham County, Tenn. The great central mound of this ancient town was protected by earthen breastworks surmounted at intervals by circular wooden towers, and completed by earthen bastions projecting 150 yards beyond the main walls. In addition to this fortified mound, there were four other eminences with tops leveled into plazas, which showed evidences of earth lodges and former buildings.

Miss Frances Densmore recorded songs of the Makah Indians at Neah Bay, Wash., in order to compare the music of Indians living beside the ocean with that of tribes living on the mountains, plains, and desert. It was found, as a general observation, that the music of the Makah resembles that of the Ute, Papago, and Yuma more than that of the Chippewa, Sioux, and Pawnee. The Makah songs recorded included songs of the whale legends and whaling expeditions, songs of the potlatch and various social dances, songs connected with contests of physical strength, "gratitude songs," lullabies, courting songs, and songs of wedding festivities.

The publications of the bureau issued during the year consisted of three bulletins, and a number of other bulletins and reports were in press at the close of the year. There were distributed during the year 13,974 copies of the publications of the bureau.

INTERNATIONAL EXCHANGES

The total number of packages handled by the exchange service during the year was 460,658, weighing 567,107 pounds, an increase over last year of 82,832 packages and 74,291 pounds in weight. This increase was due for the most part to the large number of publications received in this country for transmission to universities and colleges in Japan that lost their libraries during the recent earthquake.

The Institution was notified during the year that the Government of Hungary had established the Hungarian Libraries Board at Budapest to act as the Hungarian exchange agency, and that the

Governments of the Dominican Republic, Latvia, and the Free City of Danzig had adhered to the two exchange conventions concluded at Brussels, March 15, 1886.

The number of full and partial sets of United States official documents sent through the exchange service to depositories abroad is now 97, there having been added during the year to receive full sets the Ministry of Finance, Government of Northern Ireland, Belfast; State Library, Reval, Esthonia; and the Library of the League of Nations, Geneva, Switzerland. In addition, there is an immediate exchange of the official journal between the United States and 41 foreign governments. During the year, this immediate exchange of the official journal has been entered into with Haiti, Latvia, and Norway.

NATIONAL ZOOLOGICAL PARK

The year has been one of the most successful in the history of the park, both as to care and maintenance of the animal collections, buildings, and grounds, and in service to the public. All previous attendance records were broken by the total of 2,442,880 visitors recorded for the year. Among the 221 animals presented to the park during the year were many rare and unusual species, including a fine young Baird's tapir presented by Mr. M. G. Henery, of Honduras. This species of tapir has always been one of the rarest animals in zoological collections. Through the continued interest in the park of Mr. Victor J. Evans, of Washington, D. C., 55 animals were added to the collections including several very rare and valuable species. A most interesting collection from Brazil was brought to the park by Dr. W. L. Schurz, commercial attaché, United States Embassy, Rio de Janeiro, which included a fine South American bush dog, the first of its kind to be shown in the park.

There were 1,645 animals in the collection on June 30, 1924, including 458 mammals of 177 species, 1,059 birds of 276 species, and 128 reptiles of 41 species. The number of animals added during the year was 491, while 614 were lost through exchange, death, and return of animals on deposit. Forty-two mammals were born and 27 birds hatched in the park during the year, while the death rate was held at a normally low mark.

The 11 new yards for hoofed animals mentioned last year were completed during the year and occupied by animals in the fall. The superior arrangement of these paddocks for the care and exhibition of the animals has been favorably commented on by officials of other zoological gardens and by visitors. A new restaurant building, needed for many years, was completed during the year, which adds greatly to the appearance of the park and is much appreciated by

visitors. The most urgent present needs of the Park are a new exhibition building for birds, the present one being in very bad condition and much too small for the large crowds which visit it, and a fund for the purchase of rare and unusual animals. This fund might be increased by gift or bequest and by depositing in it certain miscellaneous revenues of the park which are now turned into the general fund of the Treasury, if this were authorized by an act of Congress.

ASTROPHYSICAL OBSERVATORY

During the year arrangements were made, through the generosity of Mr. John A. Roebling, to have sent to the Institution daily telegraphic reports of the solar constant value from the two solar radiation stations at Montezuma, Chile, and Mount Harqua Hala, Ariz. Experimental temperature forecasts for New York City, based on these daily reports of solar changes, have been regularly submitted by Mr. H. H. Clayton for certain periods of time, namely, for 3, 4, 5, and 27 days in advance and also general forecasts as to the expected departure from mean normal temperatures for the coming months and weeks. These forecasts show undoubted prevision of the temperature even up to 5 days after the solar observations. The 27-day detailed forecasts have hitherto shown no correlation with New York City temperature, but the broader forecasts for coming weeks and months have been fairly verified. The results are promising enough to warrant further trial, and through Mr. Roebling's generous support these experimental forecasts will be continued until June 30, 1925.

Three projects were undertaken at the Mount Wilson station, which the director occupied from July to October, 1923: First, to begin observations on the variations of atmospheric ozone; second, to test new improvements on the solar cooker; and, third, to measure the spectra of the brighter stars, using the 100-inch telescope and special apparatus prepared for the work. In the first project apparatus was made ready, but circumstances prevented the actual beginning of the determinations of atmospheric ozone; in the second, experiments with the solar cooker resulted in some advancement and pointed the way to further progress; and in the third highly interesting results on stellar spectrum distribution and on star diameters were obtained.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

The condition of the International Catalogue of Scientific Literature remains practically the same as it was last year. It will be

recalled that publication of the catalogue was suspended in 1921, owing to the fact that such abnormal conditions in international exchange and publishing costs had been brought about by the war that many of the cooperating nations were unable to pay the consequent increased prices of their subscriptions. However, the need of this classified index to the ever-increasing literature of science is greater now than ever before, for no publication or combination of publications has even attempted to fill its place, and it is to be regretted that so much effort is being independently expended to meet special requirements when it is evident that, should these separate undertakings be either merged or at least brought into cooperation all would be benefited and the long-felt needs of specialists and librarians thus be fully met.

The International Catalogue is in a position, through its officially recognized bureaus, to prepare index data to all of the scientific publications of the world, this being a feature which no new organization can even hope to duplicate. The local bureaus, being officially recognized and in a position of close contact with both publishers and authors of scientific papers, have unique facilities for providing the data necessary for abstracts and special indexes, and as such data is needed by all agencies supplying notices of scientific publications in whatever form, it is felt that this organization should be the foundation on which to build a cooperative service to meet the needs of all interested in scientific activities.

NECROLOGY

JOHN L. BAER

Mr. John L. Baer, employed by the National Museum for several years past as temporary assistant in the department of anthropology, died in Panama on May 28, 1924. Mr. Baer was sent to represent the Smithsonian Institution on the Marsh Darien Expedition and his death occurred in Panama just before the return of this expedition.

J. J. DOLAN

Mr. J. J. Dolan, employed by the National Museum in various capacities for 32 years, died on November 22, 1923. Mr. Dolan entered the service of the Museum as watchman and passed through the various grades until he reached the position of captain of the watch in 1903. This position he held until April 15, 1923, when he was transferred to the office of shipper, which position he held at the time of his death.

ELIZABETH D. TABLER

Miss Elizabeth D. Tabler, who had served in various offices in the National Museum for nearly 41 years, died on July 19, 1923. Miss Tabler came to the Museum in October, 1882, and served in the office of Mr. S. C. Brown, registrar, until his death in 1919, when she was transferred to the division of correspondence and documents, where she was employed at the time of her death.

Respectfully submitted.

CHARLES D. WALCOTT, *Secretary.*

APPENDIX 1

REPORT ON THE UNITED STATES NATIONAL MUSEUM

SIR: I have the honor to submit the following report on the condition and operation of the United States National Museum for the fiscal year ending June 30, 1924.

The maintenance of the National Museum for the year was provided for by a Government appropriation of $452,500 in the executive and independent offices act approved February 13, 1923, with an added item of $79,896 for increase of compensation to care for the bonus of the employees. In 1916 the appropriation to the Museum for all purposes was $426,000. Since 1916 the Museum has increased its exhibition space by the acquisition of the Aircraft Building; has materially enlarged the scope of its collections in arts and industries and in history, and has received over two and one-fourth million additional specimens, besides assuming certain definite responsibilities for the guarding and upkeep of the Freer Building. As can be readily seen, the difference in the appropriations of 1916 and 1924 hardly covers the added cost of maintaining the buildings and guarding the collections, leaving little or nothing to provide expert assistance needed in carrying out the fundamental requirement of the classification of the added collections. The growth of the Museum in all directions continues to be increasingly conditioned by its limited finances. Economies of all kinds are resorted to in making the appropriation provide first for the safe-keeping of the collections and then for their classification and exhibition. The Museum with its vast collections serves the public not as it would and could but as its limited financial resources permit.

During the year the scientific staff of the Museum was held intact with very few exceptions, doubtless due to the approaching readjustment under the classification act of 1923, which becomes effective July 1, 1924. As reported last year, tentative allocations of all positions in the Government bureaus under the Smithsonian Institution were submitted to the Personnel Classification Board by the writer as liaison officer of the Institution. The board this year reviewed, revised, and approved, with few exceptions, the allocations of the Museum employees. The few positions still awaiting the board's final approval will, it is expected, be settled within a few days. The results of the classification act are far-reaching. The scientific force

of the Museum is at last to receive adequate compensation, as a whole. There is, however, still one lot of scientific workers whose gradings must be revised to put them on an equality with similar employees elsewhere, but this will doubtless soon be satisfactorily adjusted.

The outstanding feature of this year was the addition to the Museum exhibition halls of an American colonial room, the gift of Mrs. Gertrude D. Ritter, as mentioned elsewhere in the report. This is the first period room to be permanently installed in the Museum. One of the foyer rooms in the Natural History Building has been entirely transformed and now preserves the home atmosphere of the early settlers of our country.

The time has come, with the continual stream of additions to the collections, when new objects can usually be displayed only by withdrawing from exhibition other objects, often of equal interest. The installation of the colonial room necessitated the condensation of the District of Columbia faunal exhibit.

The Museum was able by curtailing its archeological exhibition to materially assist the National Gallery of Art. The pressing needs of the gallery for additional hanging space led to the construction of a gallery 40 feet square in the west end of the east north range, second floor of the Natural History Building, to accommodate the nucleus of the National Portrait Gallery. This collection consists of the series of paintings especially made by American artists of persons prominently associated in the Versailles peace treaty—the group picture of the various delegates around the council table, and 22 individual portraits of the distinguished leaders of America and the allied nations. Designed especially for this collection, the gallery admirably fills its purpose.

A program of greater development for the Loeb collection of chemical types was made possible this year through the accrued interest on the Loeb fund, and includes the employment of a chemist to devote his entire time to its furtherance. The advisory committee on this collection was reorganized about the middle of the year to provide representation of the varied governmental agencies in Washington interested in chemistry. The committee is now constituted as follows:

Dr. J. E. Zanetti, chairman of the division of chemistry and chemical technology, National Research Council, ex officio; Dr. C. A. Browne, Chief of the Bureau of Chemistry, United States Department of Agriculture, ex officio; Dr. S. C. Lind, chief chemist of the Bureau of Mines, United States Department of the Interior, ex officio; Dr. W. F. Hillebrand, Chief of the Division of Chemistry, Bureau of Standards, United States Department of Commerce, ex officio; James K. Senior, representative of the committee in the

Middle West; Dr. C. L. Alsberg, representative of the committee on the Pacific coast; and F. L. Lewton, representative from the United States National Museum.

On the recommendation of the committee, O. E. Roberts, jr., was appointed curator of the Loeb collection of chemical types on April 1, 1924. Twenty-seven specimens were added to the collection during the year and several hundred are being prepared for presentation. It is expected that the intensive work of the next year or two will demonstrate the value of a type series of this kind.

The collections of the National Museum in the field of the arts and industries are more and more becoming recognized as a vast reference book of authentic information. Various governmental agencies rely upon the Museum's specimens for the identification and comparison of new material. Manufacturers are beginning to realize that the deposition of their products in the collections of the Museum acts as an additional protection against suits for infringement, and those who may have been accidentally granted a patent on an art that is not new. Several examples of the value of this protection have recently been brought to the attention of the Museum by patent examiners and attorneys for patentees. In one case a suit for infringement involving large damages was settled out of court upon the evidence of a Museum specimen. In two other cases the denial by the Patent Office of a patent on a product constructed upon what were claimed to be entirely new principles was found warranted after examinations of specimens in the National Museum. The old adage, "There is nothing new under the sun," is often shown to be true when an examination is made of the Museum's collections. That feature of the American patent system which denies a patent to an art or invention that has been shown to the public for two years or more increases the importance of a great collection illustrating industrial processes and products and makes it an important reference book to the United States Patent Office as well as to manufacturers, inventors, and the investing public. With the continued cooperation of American industries these collections will grow in importance and scope, enabling the National Museum to render more efficient service along these lines.

The Museum served also in the diffusion of knowledge by assisting the parent institution in its broadcasting program under Austin H. Clark, of the Museum staff, in whose charge the subject was placed by the secretary. Arrangements were made for broadcasting from Station WRC, Radio Corporation of America, a talk on the Smithsonian proper, historical in nature, and a series of supplementary talks on the various major divisions. Seven 15-minute talks were accordingly given by staff members, the first on October 19 and the last on November 16, 1923.

The conclusion was reached in the spring, as a result of careful study of radio programs, that the Institution and Station WRC could to their mutual advantage give a series of informative talks on special scientific topics. This led to the establishment of a regular Smithsonian period every Wednesday at 6.15 p. m. The Carnegie Institution of Washington and the various scientific bureaus of the Government whose work is more or less complementary to that of the Smithsonian cooperated in making possible so ambitious a project. The series was inaugurated on April 9 by a talk by Mr. Clark on "The giants of the animal world." This was followed by 10 others, equally instructive, the last on "Atmospheric electricity," by Dr. S. J. Mauchly, of the Carnegie Institution, given in cooperation with the Smithsonian on June 18, 1924. Altogether 18 items were broadcast by the Smithsonian Institution during the year, 18 different individuals participating, of whom 7 appeared under the auspices of or in cooperation with the Smithsonian and the remaining 11 as members of the staff, 7 being from the Museum. Those who participated in this program are few in number, however, as compared with those who contributed toward making it a success by furnishing information, suggestions, and encouragement. The series will, it is expected, be resumed in the early autumn.

Lack of space makes it necessary at times to refuse objects tendered for the collections, often where the Museum would like to encourage the intended donor to bring to the Museum not only his treasures but his problems also, for the Museum renders service in many ways. By its exhibition collections it conveys a message to those citizens from all parts of the land who visit their Capital; by its reserve series it affords assistance to workers in all lines here represented; by its system of distribution of duplicate specimens for educational purposes it aids the coming generation all over the land; by its correspondence it conveys desired information in response to specific inquiries in many lines; by its publications it extends the boundaries of learning; and now, by the radio its service in diffusing knowledge has been extended immeasurably.

COLLECTIONS

The total number of specimens received by the Museum during the year was 362,942, exceeding numerically the receipts of the previous year by over 70 per cent. Not only in numbers is this year's increase notable, but in scientific value as well. The increment is particularly rich in type specimens and in other specially desired material, filling gaps and otherwise strengthening the collections in many lines. Additional material to the extent of 1,187

lots, chiefly geological, was received for special examination and report.

The distribution of duplicates for educational purposes, mainly to higher schools and colleges, aggregated 8,528 specimens, duly classified and labeled. Nearly 20,000 specimens and over 90 pounds of bulk material for blowpipe analyses were sent out, in exchange for which the Museum has received or will later receive desired material in many lines. Nearly 17,000 specimens and some 24 pounds of bulk material were lent to specialists elsewhere for examination and study.

A résumé of the principal acquisitions of the year follows.

Anthropology.—The department of anthropology reports a favorable year, marked by substantial increases in its collections.

In ethnology noteworthy accessions were received from the Philippines, collected by the late Capt. E. Y. Miller, consisting of rattan fire tongs, bamboo strike-a-lights, decorated gongs, and other articles, presented by Mrs. Florence G. Miller; and a considerable number of specimens from the Araucanian, Aymara, Lengua, and Chamacoco Indians of South America, gift of D. S. Bullock.

In American archeology is noted an especially valuable collection of 95 unique ancient earthenware bowls with figures of men and animals and of group compositions from Mimbres Valley, N. Mex., received from the Bureau of American Ethnology. The possibilities of these vessels in the application of decorative art by schools and manufacturers are great. The collection is also indebted to Victor J. Evans for the loan of 88 pieces of excellent Casas Grandes ancient pottery. In Old World archeology there was added a series of prehistoric antiquities from ancient sites in France, Belgium, and Germany, collected by Dr. Aleš Hrdlička during his recent trip to Europe. In physical anthropology the most notable receipt was a large number of skeletal remains from early historic Arikara Indian village sites near Mobridge, S. Dak., collected by M. W. Stirling. The collection of musical instruments received important additions given by Hugo Worch.

The work of the department in installing, rearranging, and preserving specimens was actively carried out. Miss Frances Densmore prepared a handbook on the collection of musical instruments and aided in rearranging the exhibit. Among the numerous contacts of the department with individuals seeking information the talks given to classes and groups are most valuable and interesting. Many such talks were given by members of the staff.

Biology.—The collections received by the department of biology during the year greatly surpass those of the years immediately preceding, not only numerically but equally so in scientific im-

portance. The latter point is emphasized by the addition of a large number of species and genera new to the Museum, many gaps having been filled and deficiencies supplied. This is particularly noticeable in the division of birds, where the generosity of Bradshaw H. Swales has made possible the acquisition of many forms hitherto unrepresented in its collections.

The most outstanding accession of the year is the donation by Dr. J. M. Aldrich, associate curator of insects, of his private collection of nearly 45,000 specimens of dipterous flies, representing 4,145 named species and many unnamed, with type material in 534 species, the fruit of a busy life of collecting and study of these insects by one of the leading specialists in this important order.

The activities so auspiciously begun in China, as noted in my previous report, were continued with gratifying results during the present year. I have to record with extreme regret the tragic death of Charles M. Hoy on September 6, 1923, at Kuling, China. It will be recollected that he was sent to China by Dr. W. L. Abbott for the purpose of making collections for the National Museum, and it was during the first trip that the Museum suffered the loss of this intrepid field naturalist. Rev. D. C. Graham continued his explorations in the western part of the Province of Szechwan. During the summer of 1923 he made an expedition to Mount Omei and Tatsienlu. The collections received contained a large number of topotypes of species previously described, in addition to many new ones, some of them from very high altitudes near the Tibetan border. The National Geographic Society's expedition under F. R. Wulsin during 1923 reached the famous Tibetan Lake Kokonor, but the collections, which are of considerable magnitude, have not been received as yet. Dr. W. L. Abbott during his expedition to the island of Santo Domingo during the early winter, though paying attention chiefly to the Samana region, secured a large number of plants, reptiles, and amphibians, but the great prize was a series of skins, skeletons, and embryos representing a genus of rodents which has not been found alive for nearly 100 years. Dr. Hugh M. Smith's activities in Siam, Dr. Casey A. Wood's visit to the Fiji Islands, Dr. T. D. A. Cockerell's expedition to eastern Siberia, and Secretary Charles D. Walcott's Canadian expedition also added materially to our collections. Dr. Paul Bartsch and Gerrit S. Miller, jr., brought back extensive collections from the Bahamas and the Lesser Antilles, respectively. The National Herbarium was greatly enriched by three major expeditions to tropical America, namely, Dr. A. S. Hitchcock's to Panama, Ecuador, Peru, and Bolivia; Paul C. Standley's to the Canal Zone and Costa Rica; and Dr. William R Maxon's to Panama, Costa Rica, and Nicaragua.

The principal work of the taxidermists during the year has been the dismantling of one of the largest and oldest of the biological groups in the North American mammal hall, namely, that of the Rocky Mountain goats. The mounting of the animals for the new group, which have been collected for a number of seasons by Doctor and Mrs. Walcott during their explorations in the Canadian Rockies, has been practically finished and a fair beginning made on the rock work and other accessories. The arrangement, cataloguing, and installation of the large material received from collectors in the field has cost much time and labor, but good progress has been made and the condition of the study collections is considered very good.

As usual the Museum is under great obligations to a great number of scientific men connected with universities, museums, and other institutions all over the country and abroad, for working up such parts of the collections as are not represented by specialists on the staff of the National Museum. The research work of the members of the scientific staff has continued during such time as could be spared from the routine work, and some important memoirs have been concluded and published during the year, but the divisions are greatly undermanned, and more scientific work of a high order could be accomplished were more assistants available. With the increase in the number of accessions, the opportunity for research work becomes less.

Naturalists visiting Washington for the purpose of examining the collections have been given the widest and most liberal assistance in pursuing their studies, and loans of specimens to scientific institutions and individual investigators in this country and abroad have been made freely as heretofore. Zoological and botanical duplicates distributed to high schools, colleges, institutions, etc., aggregated 4,194 specimens, of which 2,086 consisted of mollusks in 14 prepared sets, and 800 fishes in 9 sets. Exchanges to the number of 14,526 were sent out, of which 2,737 were zoological.

The total number of specimens of animals and plants now in the collections is estimated at 7,206,816, of which 1,183,700 are plants.

Geology.—The year 1923–24 is notable chiefly on account of the unusual amount and value for both exhibition and study of the material received, a total of 227 geological accessions, aggregating 159,921 specimens, being recorded. The paleontological collections were the chief beneficiaries, the most noteworthy of the accessions being the large sauropodous dinosaur from the Dinosaur National Monument, Utah, and the Edgar E. Teller and George M. Austin collections of fossils, the last two named comprising at least 125,000 of the total number of specimens received.

The economic collections have been increased by Canadian nickel and silver ores acquired mainly through the interest of Honorary

Curator Frank L. Hess, although an instructive series of copper-nickel-silver ores was donated by the Royal Ontario Museum of Mineralogy. A series of diamond-bearing rocks from the Arkansas fields, received through the assistance of H. D. Miser, made possible a more comprehensive exhibit of the occurrence of the diamond than was heretofore shown.

The continued activities of Victor C. Heikes have resulted in the acquisition of good exhibition material to both economic and mineral collections.

An unusual meteoric iron from San Juan County, N. Mex., formed the most interesting accession to the meteorite collection, although an iron from Chile, stone from Kansas, and small quantities of other individuals from Spain and Australia added new falls and finds. These were all acquired by exchanges.

The chief contributor to the mineral collections was Col. Washington A. Roebling, who supplied funds for the purchase of new minerals and made other gifts. Radium-bearing minerals from the Belgian Congo and a number of rare species new to the collections, received as gifts and exchanges, may also be noted. The mineral collection is reported as now 80 per cent complete in species.

A number of cut gems were added to the Isaac Lea collection through the Frances Lea Chamberlain fund.

A petrographic reference series of rocks, numbering some 2,000 specimens, and thought to be without doubt the most important collection, from a scientific standpoint, now in existence, was transferred by the United States Geological Survey.

In addition to the paleontological material mentioned above, collections of Cambrian, Ordovician and Silurian invertebrates were made by Secretary Walcott and members of the staff of the department, and a quantity of foreign material was acquired through gifts and exchanges. A slab of fossil footprints from the Triassic shales of Virginia, received through the courtesy of F. C. Littleton, was added to the exhibits.

Satisfactory progress was made in the care of the collections, though a few changes are to be noted in the exhibits, the installation of mastodon and bison skeletons, a large slab of rhinoceros bones, and the slab showing footprints of a dinosaur being the most important. Expansion of the study series has occupied much of the time of the curators and their assistants. Research work, however, has progressed to the usual extent and has been greatly facilitated by the acquisition of a binocular microscope which was presented to the department by John A. Roebling.

Mineral technology and mechanical technology.—These divisions are concerned with engineering developments generally and their industrial application. The collections endeavor to visualize by

models and original objects the progress made in the mechanical and electrical fields, in mineral resource industries, and in transportation industries on land, water, and in the air. For some unexplained reason in past years these collections have been augmented spasmodically, all accessions recorded in any one year being concerned with a single one or two of the divisions' activities. This year, however, the accessions recorded, while but a little higher numerically, enhance the collections of every one of the branches in the divisions. Thus in mineral technology the glass industry exhibit was brought considerably closer to completion through the generosity of the Corning Glass Works. Two models of the most recent types of melting furnaces were presented as well as typical examples of chemical, industrial, and household oven glassware. The Cadillac Motor Co. presented one of the first automobiles made by that company in 1903 and also one of its cars made in 1923, the latter being sectioned, making visible car parts normally hidden from view.

The Automatic Electric Co. donated a complete working unit of the Strowger automatic telephone system. In this instance the exhibition case is equipped with three telephones which the visitor may operate and at the same time observe the functioning of the various parts. To the section of aeronautics there were added the Fokker *T–2* monoplane, which flew in May, 1923, from New York to San Francisco in a nonstop flight of less than 27 hours, and a helicopter type of airplane with which Emile Berliner and his son made successful flights at College Park, Md., in 1923. The water-craft collections were increased first by the addition of a model of the steamship *Leviathan*, transferred from the Alien Property Custodian, and second through the courtesy of the Canadian Pacific Railway Co., Montreal, Canada, in lending a model of the steamship *Empress of Russia*, one of the vessels of this company plying between Vancouver and the Orient.

As far as cooperative educational work is concerned, the lecture work of S. S. Wyer, associate in mineral technology, was of greatest importance. During the year he delivered 89 lectures on the subjects of fuel and power resources before many of the schools, normal schools, and colleges in Pennsylvania and before several educational groups outside of that State.

Textiles, wood technology, organic chemistry, foods, and medicine.—The collections under the supervision of the curator of textiles, which, besides textiles, embrace wood technology, foods, organic chemistry, and medicine, were increased by many gifts and by transfer of property from other Government bureaus, amounting to over 3,300 objects. The most important of these may be mentioned briefly.

Several large series of industrial specimens illustrating every branch of rubber manufacture, the manufacture of leather and

shoes, and the preparation and dyeing of seal, muskrat, and rabbit skins, were added to the collections, through cooperation with national trade associations. Exhibits were presented which show the manufacture and use of new materials from the field of industrial chemistry and include synthetic plastics and hot-molded and cold-molded compositions having high dielectric properties. These materials are used in the manufacture of electric equipment, automobile parts, musical instruments, etc. Other chemical exhibits received during the year include glues, coal-tar dyes, and artificial silk. The textile collections were increased by the gift of fibers, silk and cotton dress and drapery fabric, and a large series of hand-woven textiles; also hand looms and a commercial braiding machine. To the collections arranged to show the importance of wood and the industries based thereon were added products of the hardwood distillation industry, veneered doors, sporting goods made of wood, and paper-pulp products. The collections in the division of medicine were enlarged by 25 models showing advances in sanitary science, specimens of materia medica, and objects associated with the history of medicine in America.

Graphic arts.—The division of graphic arts held throughout the year successful temporary exhibitions of artistic prints, etchings, lithographs, and photographs, which were well attended and favorably mentioned in the press both here and abroad.

The two traveling exhibits of graphic arts were continually in demand, being displayed in 13 cities in 9 different States, and the fall and winter are already well dated up.

No entirely new and complete exhibit for the permanent collections was received, but important additions were made, especially to that of letterpress printing and to etching, the latter subject having been entirely rearranged with numerous additions, the most important of which was Miss Beatrice S. Levy's gift of three aquatint plates for her color print, White House by the Sea. This method is new to the technical series. The division now has all the regular methods of printing etchings in color.

Probably the most important accession received by the section of photography was the motion-picture camera invented by Wallace Goold Levison in 1887. This machine could expose 12 plates in rapid succession from one point. This is probably the first motion-picture camera ever made. Edward Muybridge did not have a motion-picture camera but had a row of separate cameras, each exposed as the person or animal passed in front, by the breaking of a string.

History.—The most notable addition to the historical collection was a number of objects comprising the interior furnishings of an

American colonial room, presented to the Museum by Mrs. Gertrude D. Ritter, of Washington, D. C. This collection includes wall paneling, furniture, chinaware, glassware, pewter ware, pictures, textiles, and miscellaneous objects. The wall paneling, made of American pine carved with plain designs and fastened with pegs, was taken intact from the old Bliss homestead located at Springfield, Mass., and includes a corner cupboard of three shelves with original glass doors and hinges and latches of wrought iron. In the cupboard and on the tables are shown the china, glass, and pewter ware belonging to the exhibit. The china includes an exceptionally beautiful bowl of Chinese Lowestoft and a child's tea set of the same ware, a helmet pitcher, and a number of pieces of luster ware of more than usual interest. The glassware includes several pieces of Stiegel ware, a number of plain glass mugs of antique design, a glass pitcher, and a number of glass bottles of rare types. The collection of pewter includes plates, mugs, coffee pots, pepper and salt shakers, dishes, sirup mug, and basin. This collection is unique in character and its presentation marks an epoch in the development of the collections of this type in the National Museum. It is the donor's intention to add to this collection until the furnishings of an entire colonial home have thus been assembled. These will be exhibited as a unit in a house of colonial style to be erected for the purpose in proximity to the present group of museum buildings.

To the collection of costumes of the ladies of the White House, which has for a number of years attracted so much public attention, were added two costumes of great interest. One of these is a white satin evening gown worn by Mrs. Warren G. Harding during the administration of her husband, President Warren G. Harding, 1921–1923, the gift of Mrs. Harding. The other is a gray silk dress worn by Mrs. Benjamin Harrison at the inaugural ball in 1889 on the occasion of the inauguration of her husband, President Benjamin Harrison, and donated by Mrs. James R. McKee, of New York City. Both these costumes were acquired by the Museum through the generous cooperation of Mrs. Rose G. Hoes.

The biographical collections were increased by the gift of a pair of silver-mounted flintlock pistols with leather holsters which were owned during the War of the Revolution by Maj. Gen. Charles Lee, of the Continental Army; a sword, a pair of pistols, and a pair of epaulets owned during the same period by Maj. Jacob Morris, and a number of other relics of less importance. These were presented to the Museum by Victor Morris through the Wisconsin Society of the Colonial Dames of America. Three silver camp cups owned during the Revolution by Brig. Gen. Anthony Wayne were lent by Mrs. M. W. Stroud. A gold locket containing a lock of the hair

of Napoleon I was presented by H. deB. Parsons, Miss Katharine deB. Parsons, and Livingston Parsons, of New York City. A very handsome gold snuffbox, the lid of which is set with diamonds, which was presented about 1836 to Col. René E. De Russy, United States Army, by the Prince de Joinville, was donated to the Museum by Mrs. Laura R. De Russy, of New York City. A silver tureen and platter presented to the Hon. James R. Mann, Republican leader, by Members of the United States House of Representatives, Sixty-fifth Congress, March 3, 1919, were donated by Mrs. Mann.

EXPLORATIONS AND FIELD WORK

The Museum draws its increment in large measure from explorations and expeditions undertaken chiefly by other Government agencies and by private institutions and individuals. This year the Museum benefited from an unusual number of such enterprises. Biological and botanical explorations in North America, Central America, South America, Asia, and various islands added to the collections representing the fauna and flora of various countries, while geological field work was carried on within the borders of our own continent.

During the summer and early fall of 1923 Secretary Walcott, accompanied and aided by Mrs. Walcott, was engaged on geological exploration in the Canadian Rockies in continuation of the work of previous years. Special studies were made of the Mons formation of the Ozarkian system, 3,800 feet in thickness, which on the eastern side of the Columbia River Valley was found to contain four well-developed fossil faunas, indicating its position between the Upper Cambrian and Ordovician systems of the geologic time scale. Collections of fossils illustrating new horizons in the Ozarkian system were made in this area, also in the Upper Cambrian and Silurian limestone of this region, together with small lots of desirable biological and botanical material.

Biological explorations in China included the expedition of the National Geographic Society under Mr. Wulsin along the Yellow River to Lake Kokonor in Thibet and the field work of Mr. Graham in the Province of Szechwan, and of Mr. Hoy in Hunan, all before mentioned. Mr. Graham in his trip to Tatsienlu practically duplicated the route of A. E. Pratt, going by way of Mount Omei, securing topotype material of species based on Pratt's and Potanin's expeditions as well as undescribed material which had escaped his predecessors.

Arthur de C. Sowerby continued his collecting in China for the Museum, under the auspices of Col. Robert Sterling Clark, but on account of the disturbed conditions in that country he was unable

to go far afield from his headquarters in Shanghai. The resulting valuable additions furnish serial material for comparison with collections from more remote regions.

An expedition to Japan and eastern Siberia undertaken by Prof. T. D. A. Cockerell at his own expense, primarily for the purpose of collecting and studying insects, was productive of large collections in that class with smaller lots in other natural history classes.

In Siam, Dr. Hugh M. Smith, who is engaged in fisheries investigations for the Government of Siam, collected in a number of localities birds, reptiles, amphibians, and invertebrates, important as linking up collections already in the Museum from the Malay Archipelago and Peninsula with those of the countries farther north.

In the Fiji Islands Dr. Casey A. Wood, a valued collaborator of the division of birds, enlisted the cooperation of several native collectors during a three months' visit, making very important additions of birds from that region, including many species hitherto unrepresented, a notable addition to the Fijian material from the United States exploring expedition under Captain Wilkes. Doctor Wood arranged with his local assistants to continue the work in localities he himself was unable to visit.

Under the auspices of the Bureau of Biological Survey, Department of Agriculture, in conjunction with the Navy Department, Dr. Alexander Wetmore visited Laysan, Midway, Johnson, Wake, and other islands in the Pacific and made large collections, part of which have already been transferred to the Museum.

Islands in the Atlantic were also visited. Dr. W. L. Abbott's expedition to Santo Domingo has already been mentioned, with its prized specimens of the long-lost rodent. In the Virgin Islands of the United States and the Lesser Antilles, Gerrit S. Miller, jr., curator of mammals, made extensive collections of animals and plants for the Museum at his own expense. Explorations in the Bahamas, Cuba, and the Florida Keys in August, 1923, and June, 1924, in connection with experiments in heredity which Dr. Paul Bartsch of the Museum staff is conducting under the joint auspices of the Carnegie Institution of Washington and the Smithsonian Institution, added to the Museum series of mollusks, birds and other natural history specimens from these regions. The United States Navy and the United States Army cooperated by furnishing transportation for the workers.

The expedition of A. H. Fisher to the lower Amazon River, Brazil, on which the Museum was represented by C. R. Aschemeier as mentioned in the last report, was completed early in the year. The collections made in this region included a few species of mammals and birds new to the Museum.

Under an arrangement with R. O. Marsh, John L. Baer represented the Museum on the Marsh Darien expedition undertaken in the early part of 1924, for collecting anthropological material in a region poorly represented in the anthropological collections. As mentioned elsewhere, Mr. Baer died while on this trip and the collections have not as yet reached the Museum.

Botanical explorations in northern South America conducted under the auspices of the United States Department of Agriculture, the Gray Herbarium, and the New York Botanical Garden benefited the National Herbarium. Dr. A. S. Hitchcock, custodian of grasses, on this exploration spent four months in Ecuador, two months in Peru, six weeks in Bolivia, and a few days in Panama. Large collections were obtained, of which a set of approximately 1,700 specimens, exclusive of grasses, was deposited in the National Herbarium.

Two expeditions undertaken for the Bureau of Entomology of the United States Department of Agriculture by Dr. William M. Mann, assistant custodian of Hymenoptera in the Museum, resulted in collections of insects and also specimens in other classes. The first three months of the fiscal year were spent in Mexico collecting miscellaneous insects and four months in the spring of 1924 in Panama, Colombia, Guatemala, Costa Rica, and Honduras, collecting insects, especially ants.

Another very considerable miscellaneous collection from Guatemala, of which birds formed the conspicuous part, was obtained by Harry Malleis, who visited the Province of Petén for the Bureau of Biological Survey, primarily to obtain living specimens of the ocellated turkey for introduction into this country.

During the spring of 1923 Dr. H. G. Dyar, custodian of Lepidoptera, made a trip to Panama, financed by himself, in company with R. C. Shannon, of the Bureau of Entomology of the United States Department of Agriculture, whose expenses were paid by that bureau, resulting in many thousand insects, including extensive collections of mosquitoes, in which Doctor Dyar was specially interested. Dr. T. E. Snyder, of the Bureau of Entomology, also visited Panama, securing large collections of termites which will be added to the National material.

An expedition from the Department of Agriculture to Panama and Central America was accompanied by Dr. William R. Maxon, associate curator of plants, the field work in Panama, western Nicaragua, and Costa Rica resulting in 4,500 botanical specimens. The Nicaraguan material will be especially useful in the preparation of the proposed flora of Central America.

The Panama Canal Zone and Costa Rica were visited also by Paul C. Standley, associate curator of plants, the expense of the explora-

tions being borne in part by the Department of Agriculture and by Oakes Ames, who is especially interested in the orchids of Central America. During two months in the Canal Zone there were obtained about 7,000 numbers of plants particularly desired in preparing a popular flora of the zone, and 8,000 numbers, including a large percentage of orchids, were collected during 10 weeks in Costa Rica for use in preparing the flora of all Central America.

An expedition to the west coast of the United States under Dr. H. G. Dyar was in the field at the close of the year, studying larvæ of mosquitoes. This was financed by Doctor Dyar. Dr. J. M. Aldrich, associate curator of insects, was likewise at the close of the year collecting Diptera throughout the high altitudes of the West and on the west coast of the United States and Canada. All of this material will eventually find its way into the National collections.

During the summer of 1923 the National Geographic Society continued archeological explorations at the prehistoric Pueblo Bonito in New Mexico under Neil M. Judd of the Museum staff. The material results have not as yet been officially turned over to the Museum. This was the third season of explorations which are planned to extend over a period of five summers. Mr. Judd had just started the fourth season's work at the close of the fiscal year.

A second expedition under the same auspices, also directed by Mr. Judd, penetrated a previously unexplored section of southeastern Utah, bringing back objects from basket-maker and cliff-dweller habitations.

The expedition to the Dinosaur National Monument, Utah, undertaken by C. W. Gilmore, assisted by N. H. Boss, as mentioned in last year's report, was completed in the middle of the summer of 1923. This had for its object the procuring of one of the large dinosaurs for the exhibition collections. As noted under the chapter on accessions, sufficient material was acquired for a good skeletal mount of *Diplodocus*, exceeding in exhibition value anything acquired in the department of geology in recent years, together with a considerable quantity of miscellaneous fossils representative of the Morrison fauna.

The Great Basin ranges of Nevada and Utah were the subject of stratigraphic and paleontologic work by Dr. Charles E. Resser in furtherance of Doctor Walcott's monographic studies. Of the fossils collected many were from entirely new localities.

Field work by Dr. R. S. Bassler, curator of stratigraphic paleontology, during the year included four separate projects: (1) Field work in the Central Basin of Tennessee, in cooperation with the State Geological Survey, which resulted in completing the mapping of the geology of the Hollow Springs quadrangle and in

securing fossils from that area; (2) in southern Kentucky, at the instance of Dr. Frank Springer, in search of crinoids; (3) in the Niagaran Plain and neighboring area in Ohio, obtaining information as to the region from which the Austin collection was secured; and (4) in northern Tennessee, again under the geological survey of that State, mapping the geology and securing data toward a report on the stratigraphy of the State.

The Upper Cambrian and Ozarkian systems, particularly in Wisconsin, were the subject of the field work in the summer of 1923 of Dr. E. O. Ulrich, associate in paleontology.

The reported discovery of fossil footprints on excavations in the red Triassic shale near Aldie, Va., were investigated by C. W. Gilmore, and numerous dinosaurian footprints were observed at several distinct horizons. A fine slab of these was obtained.

Shorter collecting trips to the Miocene deposits along Chesapeake Bay by N. H. Boss and to near-by localities by E. V. Shannon and W. F. Foshag provided well-preserved cetacean remains from the former and small representative collections of rocks, minerals, and ores from the latter.

The quarries at Deer Isle and Auburn, Me., were inspected by Dr. George P. Merrill, head curator of geology, who also made a geological trip into the northern part of that State.

BUILDINGS AND EQUIPMENT

For some years an additional building to house the National Gallery of Art and the history collections of the United States National Museum has been urgently needed. The removal of the art and history collections would release space in the older buildings that should provide for the growth of the other collections for years to come. The executive and independent offices act for 1924, approved February 13, 1923, authorizes the Regents of the Smithsonian Institution to prepare preliminary plans for a suitable fireproof building with granite fronts for the National Gallery of Art (including the National Portrait Gallery) and for the history collections of the United States National Museum, to be erected when funds from gifts or bequests are in the possession of the regents. A site for the building is designated in the Mall immediately east of the Natural History Building.

The National Gallery of Art Commission, which has for some time been giving consideration to the adequate housing of the art collections, decided at a meeting on December 11, 1923, to raise by private subscription $10,000 toward preliminary plans for this art and history building, and that amount was soon subscribed. The Board of Regents of the Institution accordingly on February 14, 1924,

selected Charles A. Platt, of New York City, on the recommendation of the commission, as the architect to prepare preliminary plans for the proposed building. It will be recalled that Mr. Platt was the architect of the Freer Gallery of Art. Senator Henry Cabot Lodge proposed an amendment to the second deficiency bill on April 17, 1924, appropriating $2,500,000 to begin construction of a building the total cost of which should be $7,000,000, but this failed to be enacted into law. It is to be hoped that favorable action will be taken in the next session of Congress.

The various buildings housing Museum collections have by the exercise of the strictest economy been maintained in good condition. The usual repairs were made to walls, ceilings, and roofs, and to portions of the roadway on the east of the Natural History Building. The café in the Arts and Industries Building was closed for the last two weeks in May and given a needed thorough renovation. Other changes in the same building afforded better accommodations for checking umbrellas, for the public-telephone booth, and for the watch service, and better illumination under the galleries.

The heating season was two weeks longer than the preceding one, consuming 3,267.2 tons of bituminous coal and 15.8 tons of stove coal, the former at an average cost of $7.79 per ton against $9.06 the preceding year. Minor repairs of the power plant and adjustments permitted the buildings to be more satisfactorily heated than in previous years. The electric generating equipment for the first time since the installation of the power plant has carried a load approximating its maximum capacity, due to natural increase in demand for current, as well as the addition of the Freer Building. The electric feeder leading into the Natural History Building from the Government contractor's line in B Street was enlarged to care for this increased load.

The ice plant produced 301.1 tons of ice, at a cost of $3.003 per ton, exclusive of labor. During the summer of 1923 it was unable to produce sufficient ice to meet the demands of all the buildings in the Smithsonian group. Repairs and renovation in the spring of 1924 made its output meet the demand to the close of the fiscal year.

The Museum fire-fighting equipment was given its customary regular inspections and tests, and it is expected that all deficiencies will be remedied shortly. Congress has provided for additional fire protection for the Smithsonian and National Museum Buildings by an item in the executive and independent offices act approved June 7, 1924, and arrangements have been made with the Commissioners of the District of Columbia for the installation in the Smithsonian Park of additional modern fire hydrants.

The Museum, in connection with the transfer of the Government collection of coins and medals from the Philadelphia Mint, acquired the exhibition cases in which the collection had been displayed. The

cases were built to fit a special octagonal room in the Philadelphia Mint. They consisted of four wall cases, of three sections each, built to fit the angular spaces, and a central case—a double-faced polygon of 14 units, access to the interior fronts of which is through the space which would have formed a fifteenth unit had the polygonal construction been completed. By shifting the historical collection, the west north range of the Arts and Industries Building was assigned to the collection from the mint, together with other similar material already in the custody of the Museum. The dismantling of the highly finished, many angled cases in Philadelphia and their reerection here reflect great credit upon the Museum cabinetmakers and their associates in the undertaking.

There were constructed in the Museum workshops also 13 exhibition cases and bases and 119 pieces of storage and laboratory furniture. In addition 10 items of storage, laboratory, office, and other furniture were procured by contract.

MEETINGS AND RECEPTIONS

The National Museum is prevented by its limited maintenance funds from providing public lectures, as it would like to do, on the many subjects in which it is interested. It is always ready, however, to assist as far as possible other governmental, scientific, and local organizations which so disseminate knowledge.

The auditorium and council rooms served for 105 meetings during the year, all of which were as usual open to the public. These gatherings included the National Conference on Outdoor Recreation called by President Coolidge, which met in the Museum from May 22 to 24; the nineteenth annual meeting of the American Association of Museums, May 10 to 13; the twenty-third annual convention of the National Association of Postmasters, October 10–12; one session on September 3 of the twenty-fourth annual convention of the United National Association of Post Office clerks; the meeting of the Northern Nut Growers Association, September 26–28; the meeting of adjutants general of the National Guard of each State, under the auspices of the Militia Bureau, War Department; two motion-picture exhibitions by the Public Health Service; a three-day plant quarantine conference of State and Federal representatives and an all-day conference on the Japanese beetle and the Almeria grape, both under the Federal Horticultural Board; a conference on conservation of the prong-horned antelope, under the Biological Survey; two meetings with addresses before employees of the Forest Service; a motion-picture exhibition by the Department of Agriculture, and a lecture by the Secretary of Agriculture before the American Committee on the International Institute of Agriculture; one session of the National Conference on Vocational

Rehabilitation of Civilian Disabled, under the Federal Board of Vocational Education; a series of health lectures by eminent physicians arranged by The Woman's Welfare Association on alternate Sunday afternoons from January 13 to April 27, inclusive; the celebration by the Shakespeare Society of Washington of the tercentenary (1623–1923) of the publication of the first folio of Shakespearean plays on November 7 and 8, and a benefit for the National Monticello Association by the same society on December 12; the fifth annual meeting of the American Classical League; a series of lectures for Boy Scouts and Girl Scouts; the regular meetings of the 1923–24 season of the Anthropological Society of Washington, the Entomological Society of Washington, the American Horticultural Society, and the Washington (D. C.) Chapter of the Wild Flower Preservation Society of America; two meetings by the Audubon Society of the District of Columbia; and single meetings under the auspices of the Washington Society of Engineers, the Writers' League of Washington, the Southern Maryland Immigration Commission for the purpose of organizing a garden home association, the Potomac Garden Club, the Light Bearers of Washington, the Puerto Rico Society of Washington, Federal Post No. 824 of the Veterans of Foreign Wars of the United States, the Federal Photographic Society, and the Smithsonian Relief Association.

The exhibition halls were opened for four evening receptions. On November 13 a reception was tendered to the delegates and friends of the Southern Medical Association, then holding its seventeenth annual meeting in Washington. On January 22 the Archaeological Society of Washington, affiliated with the Archaeological Institute of America, arranged for a reception in the space assigned the National Gallery or Art, immediately following a lecture in the auditorium by Count Byron Kuhn de Prorok on "Excavations in Carthage." On April 22 the regents gave a reception to the members and friends of the American Chemical Society, as a part of their spring meeting in Washington, April 21–25, which was unusually well attended. On May 22 the first floor and the foyer rooms on the ground floor were thrown open for the reception to the delegates to the National Conference on Outdoor Recreation.

MISCELLANEOUS

The number of visitors to the Natural History Building during the year aggregated 540,776; to the Arts and Industries Building, 290,012; to the Aircraft Building, 43,534; and to the Museum exhibition halls in the Smithsonian Building, 104,601.

As a mark of respect to President Warren G. Harding, all the exhibition halls, as well as the offices, were closed at noon, August 3.

1923, for the balance of that day, and again from 1 p. m. on August 7 until after the funeral at Marion, Ohio, on August 10. Visitors were also denied entrance to the Aircraft Building from January 11, 1924, to February 4, to permit of the installation of the Fokker airplane *T–2*.

The Museum published 8 volumes and 44 separate papers during the year. A publication in the bulletin series of several years ago, "The Mineral Industries of the United States—Manufactured Gas in the Home," was reprinted for a second time through the financial assistance of the author, Samuel S. Wyer. Museum publications to the number of 78,734 copies were distributed by the Museum to libraries and individuals on the regular mailing lists and in response to special requests. The distribution exceeds the number of copies printed during the year by nearly 1,000. Some 250,000 labels, representing nearly 1,100 forms, were also printed, and 163 books were bound for the library.

The Museum is more and more dependent upon donations and exchanges in building up its library, since the number of books it can purchase with its small book appropriation is constantly dwindling.

Books are very necessary tools in the classification as required by law of objects intrusted to its custody. The additions to the Museum library this year comprised 1,521 volumes and 2,667 pamphlets, making a total of 164,748 titles in the library. The number of loans made was 10,577, of which 6,139 went to the sectional libraries of the Museum.

Three members of the staff left the Museum through the operation of the retirement act: W. I. Adams, disbursing agent for nearly 20 years, with service in another bureau of the institution aggregating 28 years in all; Joseph Horan, sergeant of watch, with a service of 42 years; and A. F. Adams, classifier in the library, whose retirement, granted in October, 1923, was effective from June 2, 1921, with a service of 39 years.

The necrology for the year included Miss E. D. Tabler, clerk for nearly 41 years; J. J. Dolan, who served in various capacities for 32 years; George W. Spier, honorary custodian of watches; John L. Baer, Museum representative on the Marsh Darien expedition; and Charles M. Hoy, a field naturalist collecting in China for the Museum through the generosity of Dr. W. L. Abbott. The Museum also lost by death a number of its long-time benefactors, including Rev. Alfred Duane Pell and Ralph Cross Johnson.

Respectfully submitted.

W. de C. Ravenel,
Administrative Assistant to the Secretary,
In charge United States National Museum.

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 2

REPORT ON THE NATIONAL GALLERY OF ART

SIR: I have the honor to submit the following report on the affairs of the National Gallery of Art for the year ending June 30, 1924:

The fourth year of the existence of the National Gallery as a separate administrative unit of the Smithsonian Institution has witnessed substantial advance in directions corresponding closely with those of preceding years, although its activities have been restricted by the lack of funds for the purchase of works of art, for travel and for active promotion. The staff, limited to two members, has been occupied largely in the current work of the gallery, with receiving, recording, cataloguing and installing collections, permanent and temporary. A number of important works were received during the year notwithstanding the fact that the gallery is without suitable space for the display of additional exhibits. The discouragement due to the shortage of gallery accommodations is, however, greatly lessened by the well-grounded expectation that additions of great importance await only the fulfilling of stipulated conditions and by the further reasonable expectation that when the contemplated gallery building is completed progress will be greatly accelerated.

During the year constant effort has been made to impress upon the country the urgent need of a national gallery building, without which little progress can be made. A majority of the art works now owned by the Nation have been acquired simply because there happened to be available gallery space in the Natural History Museum in which collectors could see their treasures properly installed. Although Congress, in 1921, set aside an appropriate site for a gallery building, it was left to the Institution to obtain the funds necessary for the employment of an architect to prepare the plans and for the erection of the building. As the result of an appeal for the former purpose $11,000 was raised and Mr. Charles A. Platt was engaged on the plans, this work being under way at the close of the year. It is feared, however, that funds for the erection of the building can not be obtained in this way, since the people incline to the view that the Nation should provide a building required for purely national purposes.

It is anticipated that Congress will in the near future come to feel the urgent need of a home for the valuable works of art that patri-

otic citizens have contributed to the Nation and for the still richer contributions that may be confidently expected when a gallery building worthy of the Nation is provided. The need of an additional building in the Smithsonian group is strongly emphasized by the fact that this building when completed will be called upon to accommodate not only the arts of painting, sculpture, architecture, and all the other arts in which the esthetic is a dominant feature but the extensive collections of the department of American history which now encroach so lamentably on the space rightfully claimed by the scientific departments of geology, anthropology, archeology, and natural history.

The recent introduction in the United States Senate by Senator Lodge of an amendment to the deficiency appropriations bill providing for a gallery building gives gratifying assurance of the awakening of public interest in national art. The amendment offered is as follows:

> To enable the Regents of the Smithsonian Institution to commence the erection of a suitable fireproof building with granite fronts for the National Gallery of Art, including the National Portrait Gallery and the history collections of the United States National Museum, on the north side of the Mall between the Natural History Building and Seventh Street, $2,500,000: *Provided*, That the total cost of said building complete, including heating and ventilation apparatus and elevators, shall not exceed $7,000,000.

Among the agencies engaged in promoting the gallery's interests the American Federation of Arts has taken a leading place. The task of arousing the people to a realization of the backwardness of the art side of American culture development is intrusted to the 360 chapters of the Federation distributed widely throughout the States. In like manner illustrated lectures have been widely presented, two sets of colored lantern slides illustrating the gallery collections being in extended use, one under the auspices of the Federation of Arts and the other of the Federation of Women's Clubs. Radio broadcasting has also been utilized with good effect.

NATIONAL GALLERY COMMISSION

The third annual meeting of the National Gallery Commission was held in the regents' room of the Smithsonian Institution, December 11, 1923, the following members being present: Herbert Adams, W. K. Bixby, Joseph H. Gest, John E. Lodge, Gari Melchers, Charles Moore, James Parmelee, Charles D. Walcott, and William H. Holmes.

The secretary of the commission presented a report on the activities of the gallery for the year and reports of the standing and special committees followed.

A number of important topics presented for consideration by the commission were gone over in all necessary detail. It was stated by the secretary that the war portrait collection, after two years' circulation by the American Federation of Arts, had been returned to the gallery and placed on exhibition in association with the World War exhibits.

The committee appointed by the commission in 1922 to advise with the committee on the purchase of works from the Ranger fund, Messrs. Redfield, Melchers, and Holmes, made no report, but it was announced that during the year 11 purchases were made from this fund none of which, however, were assigned to the National Gallery.

Attention was given to the resolution submitted by the regents, February 8, 1923, requesting consideration of the suggestion of certain architects that a museum of architecture be founded in connection with the Institution. After discussion, the following resolution was adopted:

Resolved, That the Commission of the National Gallery of Art recommend to the Regents of the Smithsonian Institution the inclusion of a division of historical architecture in the National Gallery of Art. The division should seek to establish standards in architecture, furniture, and landscape architecture for the benefit of students and others interested in the preservation of the historic buildings of America.

Extended consideration was given to the important problem of a national gallery building, as to its character as the prospective joint home of national art and national history, and as to the raising of funds for the construction of a building worthy of its purpose and of the American Nation. The various agencies that might be enlisted in the work were reviewed, and the impression prevailed that obtaining funds for the purpose by subscription was not within the range of feasibility. The possible adaptation of the George Washington Memorial Building, now in course of construction, to the purposes of art and history was suggested.

It was agreed that the first and essential step was the preparation of plans for the proposed structure, and the raising of a fund for the purpose was considered. Discussion led to the announcement by a member of the commission that he would be responsible for one half of the amount required when the other half is raised. Another member indicated that he would gladly help, and a committee of three—Mr. Parmelee, Mr. Moore, and Mr. Walcott—was appointed to take charge of the task of completing the fund.

The election of officers and members of the commission and members of the committees followed. The resignation of Mr. Daniel C. French as a member of the commission was announced, and Mr. Gari Melchers was selected to succeed him as chairman of the com-

mission. Owing to the nonacceptance of election to membership on the commission of Mr. Denman Ross, Mr. James E. Fraser was elected to fill his place, and owing to a wrong understanding of the resignation of Mr. French, which was intended merely as resignation as chairman of the commission and not from membership in the commission, Mr. Joseph E. Breck was selected to fill the supposed vacancy. Mr. Breck, however, declined the appointment, making possible the restoration of Mr. French to the commission from which his resignation had been accepted under a misapprehension.

A special meeting of the gallery commission was held in the Regents' room of the Institution February 11, 1924, to consider the report of the committee appointed at the December 11 meeting of the commission to complete the raising of the $10,000 fund estimated as required for the preparation of preliminary plans for a national gallery building. Six members of the commission were present—Gari Melchers, James Parmelee, Herbert Adams, Charles Moore, Charles D. Walcott, and W. H. Holmes. The funds committee of three, Messrs. Parmelee, Moore, and Walcott, reported that $11,000 had been subscribed. The commission then proceeded to consider the question of the character of the proposed building, after which, complying with the request of the Board of Regents of the Institution, a vote was taken on the selection of an architect to prepare plans. The vote of members present, supplemented later by votes of those not present at the meeting, resulted in the naming of Charles A. Platt.

The advisory committee on acceptance of works of art met on December 15, 1923, and the following works, received subsequently to the previous annual meeting but in large part listed in the annual report for 1923, were favorably considered: Twenty-two paintings in pastel, comprising 71 portraits of survivors of the Civil War, Federal and Confederate, 50 years after the Battle of Appomattox, painted by Walter Beck; gift of the artist. Thirteen portraits painted by eminent American artists and representing distinguished leaders of American and allied nations in the war with Germany; presented by the national art committee. Bust in bronze of Jeanne d'Arc, by Madame Berthe Girardet; presented to the American Nation by the artist, through Mrs. John Jacob Hoff, in these words: "To the American people in memory of what our soldier boys have done in France at a crucial time of need"; acceptance by the Smithsonian Institution was approved by the committee. Mantel of carved white holly, with fireplace of pink Numidian marble, from the recently demolished residence of the late Benjamin H. Warder, 1515 K Street NW., Washington, D. C., Henry Hobson Richardson, architect; gift of William W. W. Parker. Four paintings, The Storm,

by Ludolf Backhuysen; seated figure of a Turk, by Eugene Delacroix; portrait of John Head, by Gilbert Stuart; and the portrait of A Lady, by Gilbert Stuart; bequest of George H. Story. The Philistines Attacked with the Plague, by Nicolas Poussin—sketch for the large painting in the Louvre, Paris; gift of W. H. Holmes. Two paintings by Sarah Paxton Ball Dodson, Wild Parsley and Une Martyre; gift of Richard Ball Dodson.

ART WORKS ADDED DURING THE YEAR

The permanent accessions for the year are limited in number and are as follows:

Four paintings, the bequest of George H. Story: Portrait of A Lady and portrait of John Head, by Gilbert Stuart; panel by Eugene Delacroix; The Storm, by Ludwig (Ludolf) Backhuysen.

Two paintings by Sarah Paxton Ball Dodson (1847–1906): Wild Parsley, painted at Belvedere, Brighton, England, being a study for the foreground of The Annunciation, a painting now in the Pennsylvania Academy of Fine Arts, Philadelphia; and Une Martyre (Saint Thecla), exhibited in the Paris and Munich Salons of 1891. Gift of Richard Ball Dodson, Esq., Brighton, England.

Portrait in pastel by Walter Beck of the naturalist, John Burroughs, painted at Woodchuck Lodge, Delaware County, N. Y., in 1912. Gift of "an admirer of John Burroughs."

L'Empereur, a large canvas by J. Carroll Beckwith (1852–1917), representing the bronze statue of Napoleon projected against a brilliant sunset, received at the gallery as a loan from the artist in 1913. Presented by Mrs. J. Carroll Beckwith in 1924.

The First Gun at Fort Sumter, by Alban Jasper Conant (1821–1915), a large canvas in which the portrait of Maj. Robert Anderson, United States Army, standing, is projected against a great gun in action. Major Anderson was in command at Fort Sumter upon its surrender in 1861 and was one of the founders of the United States Soldiers' Home, Washington, D. C. Gift of the Hon. Larz Anderson "in anticipation of the day when there shall be a national portrait gallery."

The Philistines Attacked with the Plague, by Nicolas Poussin—sketch for the large painting in the Louvre, Paris. Gift of W. H. Holmes.

LOANS ACCEPTED BY THE GALLERY

Mrs. Ralph Cross Johnson deposited a collection of 11 early Christian paintings, referred to as "primitives," by Italian, Dutch, Flemish, and Spanish masters, and indicates her intention to make

the "deposit" a permanent addition to the gallery. The list follows:

M. Albertinelli (1474–1515) : Holy Family and St. John.
Bonifazio of Venice (1491–1553) : Christ Addressing the People.
Giorgione (1477–1510), attributed to: Head of Christ.
B. van Orley (1509–1542) : Adoration of the Kings.
Josef de Ribera (1588–1656) : Judas (head).
G. B. Tiepolo (1696–1770) : Baptism of Christ; Christ in the Temple.
Rogier Van der Weyden (1399–1464) : The Entombment.
Leonardo da Vinci (1452–1519), attributed to: Head (old man).
Artist undetermined: Head of young woman.
Artist undetermined, Old Flemish: Virgin and Child (with apple).

Mrs. Ralph Cross Johnson has intrusted to the gallery for temporary care and display the following valuable works:

Sir William Beechey (1753–1839) : Portrait of the Duke of Sussex.
Sir Augustus W. Callcott (1779–1844) : St. Paul's and Black Friar's Bridge.
John Constable (1776–1837) : Large landscape, Dedham Vale; small landscape, Heavy Clouds.
William Dobson (1610–1646) : Portrait of the poet Waller.
C. Janssens van Ceulen (died between 1662–1664) : Portrait of Henry, Prince of Wales (or Prince Charles)?
J. Jordaens (1593–1678) : Portrait of Rubens' wife.
Sir Thomas Lawrence (1769–1830) : Self portrait.
Jan Molenaer (16—?–1685) : Festive scene.
Sir Henry Raeburn (1756–1792) : Portrait of a man.
Sir Joshua Reynolds (1723–1792) : Portrait of Richard Brinsley Sheridan; portrait of Lord Lifford; portrait of Mrs. Lloyd; portrait of Lord Roth.
David Roberts (1796–1864) : Interior of New College, Oxford.
William Clarkson Stanfield (1793–1867) : Marine, Approaching Storm.
Jakob van Strij (1756–1815) : Dutch landscape, with figures.
Richard Wilson (1714–1782) : Italian landscape; landscape; landscape.
Undetermined artist: Portrait of Mr. Ralph Cross Johnson.

Mrs. Marshall Langhorne, daughter of the late Ralph Cross Johnson and Mrs. Johnson, has intrusted to the gallery for temporary care and display the following valuable works:

John Constable (1776–1837) : Landscape.
Thomas Gainsborough (1727–1788) : Landscape; small landscape.
F. Guardi (1712–1793) : Scene in Venice.
John Hoppner (1758–1810) : Portrait of an Irish gentleman.
Sir Godfrey Kneller (1646–1723) : Portrait of a gentleman.
Sir Peter Lely (1618–1680) : Portrait of the Viscountess Hatton.
P. Moreelse (1571–1638) : Portrait of Judith van Volbergen.
Sir Henry Raeburn (1756–1823) : Portrait of a boy.
Jan Steen (1626–1679) : The Doctor's Visit.
Richard Wilson (1714–1782) : Landscape.

Two paintings from the bequest of Mrs. Cassie Mason Myers Julian-James to the United States National Museum: Rustic Dance, by Jean Antoine Watteau; and a Study for the Head of a Large Picture, by Van Dyck. Lent by the Museum.

Portrait of President Warren G. Harding, by E. Hodgson Smart. Lent by the artist.

Three paintings, lent by Mrs. John Biddle Porter, of Washington, D. C., which formerly belonged to her grandfather, the Hon. Richard Rush, Regent of the Smithsonian Institution, 1846–1859: Mrs. Siddons in the Tragic Muse (copy by Rembrandt Peale of Sir Joshua Reynolds' celebrated painting in the Huntington collection); Milton Dictating to his Daughter (copy by Rembrandt Peale); portrait of Hon. Richard Rush (copy of the painting by Healy).

Portrait of Associate Justice Pierce Butler, of the United States Supreme Court, by Nicholas Richard Brewer. Lent by the artist and withdrawn before the close of the year.

Miss Annie A. Wells, of Washington, D. C., has lent two medieval paintings (small panels).

Portrait of Capt. John Lawson at the age of 5, by Sir Joshua Reynolds, and portrait of Benjamin Franklin, engraved by F. Janinel, 1789. Lent by Mrs. Robert J. Walker, through Mrs. Henry T. Bull, Fort Riley, Kans.

Portrait of Chief Justice Joseph C. Hornblower and portrait of Mary B., his wife, by artist unknown; portrait of Roderick Austin, attributed to Sir Godfrey Kneller; and painting representing a sacrifice interrupted by soldiers, artist unknown. Lent by Mrs. Caroline B. Hornblower, Washington, D. C.

Portraits by Gilbert Stuart, of Benjamin and Sarah Tappan, owned by Margaret and Anna Hulett. Lent by Mr. H. K. Bush-Brown, Washington, D. C.

Portrait of the Hon. James R. Mann (1856–1922), late Member of Congress, by Gari Melchers, N. A. Lent by Mrs. James R. Mann.

LOANS BY THE GALLERY

Two paintings, Portrait of a Lady, by Andres Zorn, and the portrait of Henry Fuller, 1873, by George Fuller, were lent to the Dallas Art Association, Dallas, Tex., for its fourth annual exhibition, held November 14–28, 1923. These works have been returned to the gallery. The exhibition was international in character, and a distinguished collection was secured for display.

The Happy Mother, by Max Bohm, was exhibited at the Art Center, Washington, D. C., on the occasion of a memorial meeting to the artist, October 20–21, 1923. Mr. Bohm died on September 23, 1923, at Provincetown, Mass.

Three group portraits, comprising the Mosby triptych, from the collection of pastel portraits of Union and Confederate Veterans of the Civil War, by Walter Beck, were lent to the Brooks Memorial

Art Gallery, Memphis, Tenn., for exhibition there during the Confederate reunion in June, 1924. They have been returned to their places in the gallery.

Two paintings by J. Alden Weir—Upland Pasture and The Gentlewoman—were lent to the Metropolitan Museum of Art for a memorial exhibition of the work of that artist held in the Gallery of Special Exhibitions from March 17 to April 20, 1924. These paintings have been returned to the gallery.

Three paintings—Birch-clad Hills by Ben Foster, A Family of Birches by Willard L. Metcalf, and The Island by Edward W. Redfield—were lent to the American Federation of Arts, which assembled and sent, through the cooperation of the Department of State and the United States Shipping Board, an exhibition of paintings by American artists to be shown at the great international exhibition in Venice during this spring and summer, 1924.

Thirty paintings by contemporary American artists, largely from the William T. Evans collection, were lent to the American Federation of Arts for its traveling exhibition during the season of 1923–24. These paintings were shipped to the Michigan Art Institute at Detroit for its exhibit of August 31 to September 8, 1923, and have since been shown at Nashville, Tenn., Kansas City, Mo., Peoria, Ill., Memphis, Tenn., Lincoln, Nebr., Clay Center, Kans., and New Orleans, La. They have been returned to the gallery.

The painting by John La Farge, entitled "The Visit of Nicodemus to Christ," was lent to the American Federation of Arts for exhibition at the Carnegie Public Library, Fort Worth, Tex. Since returned to the gallery.

THE HENRY WARD RANGER FUND

Since the paintings purchased during the year by the Council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest are, under certain restrictions, prospective additions to the national collection the list may be given in this place. The names of the institutions to which they have been assigned are as follows:

Title	Artist	Date purchased	Assigned
31. The Hurrying River	Robert H. Nisbet, A. N. A	Dec. 18, 1923	Telfair Academy of Arts and Sciences, Savanna, Ga.
32. The Little Princess	Karl Anderson, A. N. A	do	Cedar Rapids Art Association, Cedar Rapids, Iowa.
33. Evening Interior	John C. Johansen, N. A	do	The Columbus Gallery of Fine Arts, Columbus, Ohio.
34. Captain Taylor's Sister.	Ernest L. Ipsen, A. N. A	do	Free Public Art Gallery, Dallas, Tex.
35. Far Away and Long Ago.	F. Ballard Williams, N. A	Apr. 14, 1924	Arnot Art Gallery, Elmira, N. Y.

Title	Artist	Date purchased	Assigned
36 Midsummer	William S. Robinson, N. A	Apr. 7, 1924	
37. The Bathers	Spencer Nichols, A. N. A	do	
38. The Little Princess	Arthur P. Spear, A. N. A	do	Waco Art League, Waco, Tex.
39. The Necklace	Richard E. Miller, N. A	Apr 14, 1924	
40. The Brook at Carversville.	E. W. Redfield	do	Free Public Library of Jersey City, Jersey City, N. J.
41. Clearing after September Gale—Maine Coast.	Howard Russell Butler, N. A	Apr. 7, 1924	

SPECIAL EXHIBITIONS HELD IN THE GALLERY

A collection of nine paintings by the Tuscan artists Francesco Gioli (1846–1922) and Luigi Gioli, lent by the Royal Embassy of Italy, Washington, D. C., was shown on screens in the totem-pole room at the south end of the gallery.

A special joint exhibition of paintings by Savely Sorin and sculptures of Seraphin Soudbinine was held in the large central room of the gallery. The opening view, cards for which were issued by the Smithsonian Institution, took place on the afternoon of January 10, from 2 to 4.30. The exhibition closed on January 27, 1924.

An exhibit of the art work of Viennese children, pupils of Professor Cizek, of Vienna, was held in the lobby of the Natural History Building, under the auspices of the American Federation of Arts, May 7 to 19, 1924. This exhibit is being circulated in this country under the auspices of the Rockefeller Foundation.

INSTALLATION OF THE WORLD WAR PORTRAITS

In the annual report for 1923 a brief account was given of the painting and subsequent history of the World War portrait collection provided by the National Art Committee, and it may be desirable here to repeat the statement there made to the effect that the original plan for the acquirement of the collection for the Nation has not as yet been fully carried out. In order that the gift of these portraits might have a distinctly national character, it was planned that a group of two or more, financed by citizens of any city, should be inscribed as presented by that city. Thirteen of the portraits were in this manner added to the national collection, while eight await the reawakening of the patriotic impulse that inspired the original movement in behalf of a World War collection.

In 1921 the collection was turned over to the American Federation of Arts by the committee for exhibition purposes, and was shown in 25 of the principal American cities. On arrival in Washington, June 12, 1923, the portraits, 20 in number, and 1 portrait group, supplemented later by a portrait of the Queen of the Bel-

gians, were installed in the foyer of the New National Museum, in direct association with the great collection of World War historical exhibits. This proved unsatisfactory, however, and space was finally provided on the second floor of the Natural History Museum, where partitions were erected inclosing a floor space 34 by 37 feet. This improvised gallery, artificially lighted, although separated from the gallery proper, proved to be quite satisfactory, and the portraits are shown to good advantage.

DISTRIBUTIONS

Loans have been withdrawn by their owners as follows:

Evening; Junipers in Winter, by Ludwig Dill; withdrawn by the American Federation of Arts.

Portrait of Associate Justice Pierce Butler, of the United States Supreme Court, by Nicholas Richard Brewer; withdrawn by Mr. Butler.

Forty-one paintings by Ossip Perelma; withdrawn by Mr. Perelma.

Portrait of San Lorenzo Guistiniano, by Gentili Bellini; withdrawn by the American Red Cross through Miss Irene M. Givenwilson, curator of the Red Cross Museum.

Painting entitled "A Prayer to St. Genevieve," by Mme. la Marquise de Wentworth; withdrawn by Dr. J. H. Gore.

NECROLOGY

The announcement of the death of Ralph Cross Johnson on July 9, 1923, at his summer home, city of Belfast, Me., where he and Mrs. Johnson had settled for the summer, came as a great surprise and is deeply regretted by the Smithsonian people, and very especially by the staff of the National Gallery. Mr. Johnson's gift to the gallery of masterpieces of painting is regarded as one of the richest contributions ever made to the art treasures of the Nation.

The Rev. Alfred Duane Pell, D. D., of New York City, a benefactor of the gallery, died in April, 1924.

Appended to this report is a list of portraits and portrait sculpture, approximately 450 in number, belonging to the Smithsonian Institution and its branches (not printed). It is intended to serve as a record of the Institution's collections in these branches and for convenience in organizing the contemplated national portrait gallery.

Respectfully submitted.

W. H. Holmes, *Director.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 3

REPORT ON THE FREER GALLERY OF ART

SIR: I have the honor to submit the fourth annual report on the Freer Gallery of Art for the year ending June 30, 1924.

THE COLLECTION

Work completed during the year includes the examination, classification, and cataloguing of Chinese and Japanese stone sculptures and paintings. Further work has been done in the preservation of oil paintings; 40 Whistler water colors and pastels have been reframed, and the titles of those on exhibition have been painted upon the frames. The relettering of titles and references upon the mounts of Whistler etchings and lithographs is well advanced and the work of remounting a certain number has been begun.

Identification photographs of all objects in the collections of pottery, stone sculpture, jade, and bronze, and of a number of Chinese paintings in panel form have been made. These photographs are mounted upon the cards of the general catalogue and provide an easy but accurate means of reference which saves much handling of the collections. In response to requests other photographs and slides have been made, reproducing not only objects in the collection, but also cases and other details of installation, as well as views in and about the building.

During January and February a special exhibition of 136 Whistler etchings, dry points, and lithographs was on view in Galleries I, II, III, and IV. In May the Chinese *makimono*, shown in Gallery XIV, were installed in cases built to receive them. Other changes in exhibition involved 42 oil paintings, 14 water colors, 20 pastels, 5 Indian paintings, 3 Persian paintings, 2 Chinese paintings, 2 Chinese bronzes, 2 Chinese sculptures, 1 piece of Korean pottery, 1 Japanese painting.

One thousand four hundred gallery books, giving detailed information about objects on exhibition, have been compiled, mimeographed, and bound for use in all the Whistler galleries, including the Peacock Room. Through the courtesy of the Boston Museum of Fine Arts, the *Synopsis of History*, a parallel chronological table prepared for the use of students, has been issued in a Freer Gallery edition, which has had a second printing of 500 copies, while our

pamphlet giving general information about the gallery and collections has reached a third printing of 3,000 copies. One thousand four hundred and eighty-two copies of the foregoing publications have been sold at the north entrance and on order.

Additions to the collections by purchase are as follows:

BRONZE, CHINESE

23.1. Ceremonial vessel of the type *chia*. Chou dynasty, 1122 to 255 B. C.
23.2. Toilet box of the type *lien*. Six Dynasties, sixth century (?).

PAINTING, INDIAN

23.3. Jaina Illuminated MS. of the Kalpa Sūtra, fifteenth century.
23.7. Pañcama Rāginī. Rajput, Rājasthāni. About A. D. 1600.
23.8. The gracious manifestation of Devī. Rajput, Rājasthāni, seventeenth-eighteenth century.
23.9. The death of Bhīsma. Rajput, Pāharī (?) seventeenth century (?).
23.10. Damayantī's Wedding Procession. Rajput, Pāharī (Kāṇgrā). From the Nala-Damayantī series. Late, eighteenth century.
23.11. From the Nala-Damayantī series. Rajput, Pāharī (Kāṇgrā). Late eighteenth century.
23.12. From the Nala-Damayantī series. Rajput, Pāharī (Kāṇgrā) Late eighteenth century.
23.13. From the Nala-Damayantī series. Rajput, Pāharī (Kāṇgrā). Late eighteenth century.

PAINTING, PERSIAN

23.4. Burning Idols. About A. D. 1350.
23.5. From a Shah Namah MS. Zoḥak feasting. About A. D. 1300.
23.6. Majnun. About A. D. 1500.

SCULPTURE, CHINESE

24.1. Taoist divinities and floral designs. Engraved limestone lunette. T'ang dynasty, seventh-eighth century.
24.2. A Buddhist procession of musicians and a dancer. Limestone relief. T'ang dynasty, eighth-ninth century.

Additions to the library, by gift and purchase, comprise 7 maps, 134 pamphlets, and 145 books and periodicals in various Asiatic and European languages. A list of these additions accompanies this report. (Appendix A, not printed.) The necesary work of examining the Chinese texts for omissions and duplications due to faulty printing and binding has been begun and is still under way. Seventy-four volumes of European books have been rebound.

BUILDING AND EQUIPMENT

The workshop has built during the year, one 15-foot case, three 12-foot cases, and two 9-foot cases, with easels to be placed in them; also, four 70-inch cases, two small square cases, and six stands for

objects shown in cases. Six new wooden frames for cases were made and the glass tops for these assembled. For this work a table and rack with a metal pan was built. Two new pedestals for stone sculptures were built and the sculptures mounted. The shop has made also 40 butternut picture frames, which were sent away to be gilded, 58 reeded French walnut frames, 24 frames for gallery and other signs, and one large American walnut frame for hanging a six-fold screen. In the autumn a removable vestibule door for winter use was built and installed at the north entrance. In connection with the use of the auditorium, the shop built a portable wooden platform to be placed at times on the concrete stage, and fitted up closet No. 10 as a cloak room, made a stand and lockable cover for the projection lantern, built a portable barricade, and rehung the door leading from the auditorium to the emergency exit. Locks were placed on all storage cases in storage rooms 3 and 4, and numerous fittings, such as bronze clamps for *makimono* on exhibition, a map drawer in the curator's office, a device for hanging *kakemono* for examination, stands with frames for notices, etc., were made.

A portable scaffold was built for use in the court in cleaning windows; the joints of the coping of the main walls and court walls were covered with felt and cement; a picture molding was put on the west wall of study room No. 1; one section of a new device for modifying the light has been made and installed in the attic; and miscellaneous repairs have been made on objects in the collection and on furniture and building.

The shop has also recolored the east wall of Gallery XVI, painted the floor of study room No. 2, painted numbers in the various sections of attic and sub-basement in accordance with the architect's plan, painted the underside of the skylight glass, and lettered and painted several signboards. In the summer of 1923 the lettering for the inscriptions to be placed on the outside of the building was done by the shop painter after the architect's design, and later the inscriptions were cut by outside contract. By outside contract, also, weatherproof shades were put outside the north and south corridor windows.

To the general equipment have been added during the year a mimeograph, a stereopticon lantern, and several pieces of office furniture.

The Freer Gallery is gratefully indebted to the Bureau of Fisheries for the gift of goldfish for the fountain, to the Zoological Park for the loan of three peafowl, and to the Department of Agriculture for advice as to the care of the box trees and rhododendrons in the court and for constant oversight of them.

ATTENDANCE

The gallery has been open every day, with the exception of Monday, from 9 o'clock until 4.30, and with the exception, also, of four days when it was closed by Executive order at the time of the death of President Harding. The total attendance for the year was 111,942. The aggregate Sunday attendance was 28,925, making an average of 546; the week-day attendance amounted to 83,017, with an average of 324. Of these visitors, 482 came to work in the study rooms or to examine objects not on exhibition; 70 to make a study of the building, storage facilities, lighting, wall-coloring, etc.; 10 to make copies or studies from objects in the collection, and 35 brought objects in their possession for examination and information.

On February 7, 8, and 9 the auditorium of the Freer Gallery was placed at the disposal of the Library of Congress for the presentation of three recitals of chamber music. These concerts were the gift to the Library of Mrs. Frederic Shurtleff Coolidge, to accompany her gifts of the manuscripts of 13 modern compositions to the music division. Seven of these were performed.

On April 29 Professor Paul Pelliot, of the Collège de France, gave an illustrated lecture on "Chinese bronzes, jades, and sculptures." The total attendance at the concerts was 1,080, and at the lecture 202, making a grand total attendance for the gallery of 113,224.

PERSONNEL

Miss Grace L. McKenney entered as an assistant on October 22, 1923.

Miss Mildren M. Tytus worked as an assistant from November 12 to May 17.

Mrs. Rita W. Edwards was transferred from the office of correspondence and documents on February 16, and was regularly appointed to the position of stenographer on April 1.

Miss Chie Hirano, librarian of the department of Chinese and Japanese art of the Boston Museum of Fine Arts, and Mr. K. S. Wang, have worked on the cataloguing of Japanese and Chinese books.

FIELD WORK

Since the activities of the expedition sent to China under the joint auspices of this gallery and the Museum of Fine Arts, Boston, have been conveyed to you in detail from time to time through the reports and correspondence of the field staff, I venture merely to remind you now of the fruitful investigations carried on during the year at Hsin-chêng Hsien in Honan; at I Chou in Chihli; at the tombs of Han Wu Ti, Ho Chü-ping, and others in Shensi; and,

latterly, at Yü-ho Chên in Honan, where some burials of the Han dynasty have been thoroughly investigated with gratifying results. But important as the archeological work of our expedition has been, we are more to be congratulated, perhaps, on our success in establishing between ourselves and the Chinese authorities a cooperative agreement with regard to archeological investigation which has been confirmed by the unsolicited appointment of Mr. Bishop as Honorary Adviser in Archeology to the Historical Department of the Chinese Government. An arrangement of this sort was conceived as the fundamental object of our expedition, and its accomplishment marks the first definite effort of the kind to bring Chinese archeologists and officials together in a mutually beneficial and dignified relationship with western archeologists and museums, thus providing in some measure, at least, a working basis on which a more enlightened scholarship may flourish and gradually supplant, let us hope, the ruthless and unscientific collecting of Chinese antiquities on a commercial scale which has hitherto been allowed and even encouraged to furnish so much of the material available for students in this vast and increasingly important field.

Mr. Bishop's detailed account of his field activities accompanies this report as Appendix B (not printed).

Respectfully submitted.

J. E. Lodge, *Curator.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

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APPENDIX 4

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: I have the honor to submit the following report on the researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ending June 30, 1924. These were conducted in accordance with the act of Congress approved June 12, 1923, which contains the following item:

American ethnology: For continuing ethnological researches among the American Indians and the natives of Hawaii, including the excavation and preservation of archeologic remains, under the direction of the Smithsonian Institution, including the necessary employees and the purchase of necessary books and periodicals, $44,000.

The Bureau of American Ethnology was founded by Maj. J. W. Powell and placed under the direction of the Secretary of the Smithsonian Institution by act of Congress. This bureau is devoted to the increase of knowledge of the American Indian, as well as of the natives of Hawaii and the aborigines of Porto Rico. It follows the ideal of the Smithsonian Institution as applied to researches on the American Indians, including all branches of their archeology and ethnology. The bureau publishes annual reports and bulletins, the whole number of these thus far published being 40 reports and 81 bulletins. The former assume the form of memoirs, often large and highly technical; the latter are generally smaller in size, often preliminary in character.

The fundamental idea which led to this appropriation was the recognized necessity for reliable information for a proper appreciation of the Indian, as an aid to legislation. Very extravagant and diametrically opposite opinions were rife regarding the character of our aborigines. In the early days of contact of the European and Indian races erroneous romantic ideas were largely prevalent, but with the application of the science of anthropology new values of Indian character developed. The Indian in some quarters was regarded solely as an object of research; the humanitarian side was lost sight of, and the fact that he is a man belonging to one of the most important races in the ultimate amalgamation of the different peoples was overlooked. The aim of the Bureau of American Ethnology is to discover and to disseminate correct ideas of the Indian as a race, that our people may better understand and

appreciate his history, language, sociology, music, religion, and various arts and industries. It is obligatory for the bureau to preserve accurate records of customs indigenous to America that are rapidly being lost in the settlement of the former homes of the Indians by members of the white race. The value of this material will increase in coming years, for the records that are now being made are final and in many cases will be the sole objective information that posterity will have of the Indian and his customs. This work is imperative, for within the past few decades a great deal of information of this kind has disappeared unrecorded, and the probability is that this generation will witness the death of most aboriginal survivals in culture.

While the ideal of the bureau is the acquisition of knowledge and the publication of the same through reports, there has grown up a great deal of work on related subjects that absorbs more or less of the time of the chief and his staff. Information is sought from all quarters regarding the Indians, and urgent calls from State institutions and universities asking for advice and help in local problems have been more numerous than at any other time in the history of the institution. Routine office work has assumed in the past ten years a larger relative proportion than in former decades. Various agencies have quickened interest in the problems considered by the Bureau of American Ethnology. The great increase in travel resulting from the development of the automobile and the foundation of national parks has intensified the desire to "see America first." Our parks and Indian reservations have been visited in the past few years by an ever increasing number of travelers. This has stimulated a demand on the part of the general public for accurate information on the history and customs of the Indians, which the bureau endeavors to supply.

It can not be expected, when the office work has grown to such magnitude and the appropriations have remained practically the same as they were before the war, that the quantity of research in the field can equal that of former years, but the chief has endeavored to have as many of the staff in the field as he can and to publish the reports of their work as rapidly as feasible. It is self-evident that the acquisition of knowledge regarding the Indians, even if not published, is a most valuable asset, notwithstanding the fact that it must be stored in the archives to await a more favorable time for publication.

The first duty of the chief being administrative and his time for a large part of the year being occupied with routine matters, he does not have much opportunity for field work, but notwithstanding this fact scientific work of a limited nature has been done by him

in the field. He has kept en rapport with the work of all archeological expeditions in the Southwest in order to be able to advise you in regard to your recommendations for archeological work on the public domain. The number of expeditions in the Southwest has tripled or quadrupled in the last decade.

The field work engaged in by the chief during the past year was archeological in nature, in cooperation with Mr. E. M. Elliott and his associates, of St. Petersburg, Fla. There are few areas in the United States which promise more to the archeologist than southwestern Florida along the shore from Tampa Bay to Cape Sable. Perhaps no one has added more to our knowledge of this area than Mr. F. H. Cushing, a former ethnologist of the bureau. The problems of southern Florida demand more objective material than we have from the Everglades and the Ten Thousand Islands, where numerous proofs of a vanished population are in evidence in the form of enormous shell heaps and earth mounds.

The chief began his researches on Weeden Island, near St. Petersburg, which is situated at the end of Gandy Bridge, an artificial causeway crossing Tampa Bay. The evidences of prehistoric aboriginal life on Weeden Island are numerous large shell heaps and sand heaps which may be divided into groups or types, as kitchen middens, observatories, foundations of houses, and burial places. Evidently there was formerly a large village near the highest point of the island. One of the mounds which was chosen for excavation turned out to be a cemetery, and in the course of the winter about one-half of it was excavated. The work extended from November until March, inclusive.

The chief was not able to be in St. Petersburg the whole winter, but after having started the work in November, 1923, he returned to Washington, assigning the direction of the excavations to Mr. Stanley Hedberg and later to Mr. M. W. Stirling, of the National Museum, who continued the work until the chief's return in February. As a result of the excavation a large collection of aboriginal objects was brought to the United States National Museum. This collection contains many unique specimens and will later be permanently installed in the Museum upon completion of a report on it. No specimens had formerly been excavated at Weeden Island and the unique results of this work are regarded as most important. A preliminary report has been published in the Smithsonian Miscellaneous Collections, vol. 76, No. 13.

At the present time it is too early to draw final conclusions from the above work, but it is intended to continue excavations in Florida in the winter of 1924. Many of the specimens found were not very different from those characteristic of the west coast of Florida, but the number of objects is greater and their variations so extensive

that they are thought to indicate a high development of the aboriginal culture in southern Florida. Evidences of two distinct cultures, one above the other, were determined from the excavations in the Weeden mound. The lower contained crude pottery, very few implements, mostly of shell, all having a considerable likeness to the so-called archaic Antillean culture of Cuba. The upper layer contained very fine specimens of decorated pottery in great numbers, showing close relationship to the ceramics of Georgia This indicates an extension southward or a drift of population possibly allied to the Muskhogean, into the peninsula. The relationship of the people of the lower layer was Antillean rather than Muskhogean. The inhabitants of southern Florida, when the earliest burials were made in the Weeden mound, probably belonged to an unknown tribe. The artifacts in the upper layer may be remains of the Caloosa tribe, which was found there when Tampa Bay was visited by Ponce de Leon. The Indians that now inhabit the Everglades—the Seminoles—are a late introduction into Florida and of Creek descent. The numerous Florida shell heaps antedated their advent by several centuries.

The chief has actively worked during the past year for the formation of a new national monument on the Little Colorado, near Flagstaff, Ariz. This monument has been temporarily named the Wupaki National Monument and includes ruins at the Black Falls of the Little Colorado, first described by him in 1900. It is to be hoped that before another report this most interesting group of stone buildings will be added to the other archeological monuments. The ruins that comprise it have some of the best preserved walls in the Southwest.

The impression exists in some quarters that the work of the Bureau of American Ethnology must be completed in a certain definite time. This impression has no real foundation, for ethnology is like any other scientific study and has no limitations. Every new year of work in the bureau enlarges the horizon of research and presents new problems regarding the American Indians for solution. Since the foundation of the bureau by the late Maj. J. W. Powell the aims and tendencies of the science of ethnology have greatly enlarged, and the published studies of the staff have put the science of anthropology upon such a firm foundation that not only the past appropriations but also the prospective expenditures by Congress are more than justified. The earlier work covered a limited scope; it pointed out the field for future work. It now remains for the comparative ethnologist to connect the various problems of man and his culture and to shed new light on what still remains unsolved. By law the ethnological research of the staff of the bureau is limited to the American Indians and the aborigines of Hawaii. The logical

outcome is the enlargement of the Bureau of American Ethnology into a bureau devoted to the study of all races.

Even in studying the Indians there are great regions of South America which are practically unknown to the ethnologist. South America, next to Central America, contains examples of probably the highest culture that has ever been attained by the American race. I refer, of course, to the civilization of the great empire of the Incas, extending from the Isthmus of Panama to southern Chile. In this prolific field the bureau has done comparatively little, and the time is now ripe for an extensive exploration in that field. No less important in South America is the area inhabited by wild tribes, such as the Matto Grosso and other regions east of the mountains. The remarkable similarity of the culture of the Indians in Argentina and that of the pueblos especially pleads for more thorough investigation of the former area. The great valley of the Amazon, that has attracted the ethnologist since the wonderful voyage of Alex. Von Humboldt at the beginning of the last century, still holds out new problems.

The bureau will soon issue a remarkably complete work by Dr. Walter E. Roth on British Guiana, which probably will be one of the finest it has ever published. It adds much to our knowledge, but no more important fact than the magnitude of the numerous fields remaining to be investigated in northern South America. The languages, sociology, religion, arts, history, and archeology of almost every country in South America demand research. Here we have a great continent awaiting the student of the antiquity and cultural relationship of the American race.

In the same way the field of Central America and Mexico now awaits the investigator, although in that particular area the bureau has made some very important contributions.

There remain special problems of secondary nature throughout the continent that are as yet unanswered which would be within the scope of the bureau's work. All ethnological work on the South American Indians should have very great influence in uniting more firmly the republics of Spanish origin and the United States.

Of the many problems awaiting investigation, one of the more important is the plotting of the trails by which communication was carried on between Indian tribes. These trails historically followed by roads and railroads now serve the growing habit of the automobile and the desire of Americans to see their own country. A study of the foods used by the Indians has a practical value which can not be overestimated. The number of plants used by the Indians far outnumbers those on our own table, and the bureau might well give attention to the discovery of new food resources.

It is desirable to increase the archeological work of the bureau which thus far has attracted a great deal of attention and which is one of the foremost departments of anthropological study. This study should be extended to Florida and the coast States with a view to determining the relationship of the antiquities of North and Central America. The investigation of the southwestern portion of Texas and the adjoining State of New Mexico should be exploited, especially the contents of the new national monument near Carlsbad which contains important archeological material. One important problem is to follow the extension northward of the Huaxtec culture along the shores of Tamaulipas and Texas to our southern mound builders.

During the fiscal year Dr. John R. Swanton, ethnologist, completed the translations of stories from his Koasati, Alabama, Hitchiti, Natchez, and Creek texts, and added to them the stories obtained only in English and those in the Tuggle collection; he provided these stories with footnotes referring to similar tales among other tribes, and prepared an introduction for the whole. In addition to this work he has edited and largely recast a manuscript on Indian trails by the late Mr. W. E. Myer. Also, with the assistance of Miss Atkins, he has begun incorporating into an alphabetical card index all words in the Timucua language contained in the religious works of the Franciscan missionaries Pareja and Movilla—nearly all that is left to us of this old Florida tongue. Nearly one-third of the work has been completed.

On the 1st of July, 1923, Dr. Truman Michelson, ethnologist, was on board the *Sagona* en route to Labrador. He reached the Northwest River on July 4, where he found a few Nascapi Indians, one from Davis Inlet, besides the ordinary Montagnais Indians of the vicinity. From his work among these Indians it follows that the language of the Nascapi and Davis Inlet Indians is the same, and that instead of being a wholly distinct language it is nothing but a Montagnais dialect. Furthermore, it is abundantly clear that the dialects of the above-named Indians form a distinct unit as compared to the Montagnais dialects of Lake St. John and Lake Mistassini, as well as the so-called "Cree" of Rupert's House and the East Main River, which really are not Cree at all but Montagnais dialects. The report of some Indians to the west of the Nascapi speaking a language unintelligible to them is worth investigating at a later date. It may be noted that the folklore of the Indians of Labrador contains more elements occurring among Central Algonquians than has been suspected. The very simple social organization of the Labrador Indians makes it very probable that the rather complex organizations of the Central Algonquians are unoriginal and are

due both directly and indirectly to the influence of non-Algonquian tribes. He was able to measure only a few of the Indians at the Northwest River, so it is not possible to state precisely which physical type they represent.

At the conclusion of his work he returned to Rigolet and left on July 22 for St. Johns, Newfoundland. En route he was able to take the measurements of a few Eskimos. On his arrival at St. Johns he proceeded by steamer and train for Tama, Iowa, to renew his researches among the Fox Indians. He devoted especial attention to the ceremonial runners of these Indians, and in the course of the winter submitted a manuscript on them for publication by the bureau. Further, a number of Fox texts were translated and other ethnological data obtained. Doctor Michelson returned to Washington near the close of September. He made another trip among the Foxes in May and returned to Washington toward the end of June. During this trip he obtained new data on Fox ceremonials.

By joint arrangement with the Museum of the American Indian, Heye Foundation, the bureau undertook in the summer of 1923 the excavation of the Burton Mound at Santa Barbara, Calif., which was the chief village of the Santa Barbara Indians and without question the most important archeological site on the southern California coast. Mr. J. P. Harrington, ethnologist of the bureau, was detailed to take charge of the exploration of the mound and the work was commenced early in May, 1923, and continued throughout the summer and fall. The first day's work revealed the location of the cemetery, just where old Indians had stated that it was situated. During several months of careful stratigraphical excavation many facts of interest for the prehistory of the Santa Barbara Indians and the early culture of the Pacific coast in general were recorded.

The principal rancheria or village of the ancient Santa Barbara Valley was not at the mission, where the Indians were later gathered, but at the beach. It was situated just west of the mouth of Mission Creek, where a landing cove for canoes and two low mounds, one by the beach and a larger one 650 feet inland and now known as the Burton Mound, afforded unusual attraction as a dwelling place for Indians. At a number of places in the locality were sulphur springs; also springs of good drinking water. The name of the village was Syujtun, meaning "where the trail splits." There a thriving population of some 500 Indians lived on the wild food products of the neighboring shore and sea and of the Santa Barbara Valley, rich in acorn-bearing oaks and game animals.

The inhabitants of Syujtun remained unmolested until the establishment of the Santa Barbara Mission in 1786. After this the native villagers were gradually removed to the adobe cuarteles of the mission, 2 miles distant, and the desolated beach was known as "el

puerto de Santa Bárbara" or as "el rancho de la playa." After the confiscation of the mission lands the ownership of the beach ranch passed into private hands. During the forties the owner was none other than Capt. George C. Nidever, known in California history as the rescuer of the last surviving Indian woman from San Nicolas Island. Captain Nidever sold the property in 1851 to Augustus F. Hinchman, whose daughter, Miss Stella F. Hinchman, has furnished valuable data about the history and traditions of the mound. In 1860 Mr. Hinchman sold the tract in turn to Lewis T. Burton, who made it his home for 19 years and after whom the mound has been called in more recent times. None of the early owners had allowed excavation on the property and with erection of the Potter Hotel on top of the mound in 1901 all hope of archeological investigation was lost. This hotel burned to the ground on April 19, 1921, and the old village site was thereby again released for archeological investigation.

The results of this excavation of the Indian town of Santa Barbara proved rich and interesting beyond expectation. The graves that were opened were crowded with human bodies, trinkets, and a great variety of utensils. Among the rarest specimens are the largest soapstone canoe ever discovered in California, a wooden awl such as is described by the early historians, and a number of objects of problematical use. There are soapstone pipes, fishhooks of abalone and bone, sinker stones, arrowheads of great variety, spearheads, about 140 fine mortars, pestles, including some very long ones, beads of many kinds, pendants, daggers, bowls and kettles of soapstone, including some of the largest ever found, native paints, etc. About 300 skeletons were taken out, among them some very ancient skeletons from the coquina or reef-rock layer. These are now in the hands of Dr. Bruno Oetteking, of the Museum of the American Indian, who is preparing an elaborate report on them.

At the close of January, Mr. Harrington returned to Washington and has since then been engaged in the preparation of his report on the Burton Mound.

Mr. J. N. B. Hewitt, ethnologist, was engaged for the greater part of the year in office work. This consisted chiefly in the historical analysis of the large mass of material in native text relating to the formation and structure and import of the League or Confederation of the Five Iroquois Tribes or Nations. He was also occupied in the translation of the farewell address of Deganawida, a founder of the confederation, into literary English. In this address Deganawida briefly summarizes the scope and import of the institutions and the laws of the league; herein, with the mas-

terful hand of a prophet-statesman, he also graphically recapitulated the work accomplished by the several co-working founders.

Mr. Hewitt also translated from the Onondaga text the laws first recognizing the extant institution of chieftainess in uterine kindreds and then adopting it for the purpose of making it fundamental among the institutions of the League of the Iroquois, the laws defining the duties, rights, and obligations of the incumbent of such office and carefully prescribing the method by which a woman should be nominated by the mothers of her own uterine kindred, the method by which the choice should be confirmed, first by her own, and then by sister, and then by cousin clans, and then finally how this candidate should be installed at a federal council of condolence and installation. These laws also prescribe the method by which such chieftainess can, for cause, be deposed and a successor nominated and installed as prescribed by these laws; and they also prescribe the method of nominating and installing the male aid to the chieftainess, who must be a warrior and an orator to fulfill his adjuvant duties.

As a member of the United States Geographic Board, representing thereon the Bureau of American Ethnology, Smithsonian Institution, Mr. Hewitt has attended all regular and special meetings of the board with a single exception. As custodian of manuscripts of the Bureau of American Ethnology Mr. Hewitt reports that more than 250 items were withdrawn and consulted by the various collaborators of the bureau and by other students.

In past years, in studying the social and political institutions of the Iroquoian peoples, especially of the Five (latterly Six) Nations or Tribes, Mr. Hewitt has spent a number of field seasons in carefully collecting and recording in native texts from the best available leaders, chieftains, chieftainesses, ritualists, and ceremonialists, chiefly in the Mohawk, Onondaga, and Cayuga dialects, extensive material and data concerning the principles, the laws, decrees and ordinances of the instituting councils, the set rituals, the prescribed chants, and the ceremonial addresses, which together defined the functioning apparatus of the great commonwealth, commonly called the League or Confederation of the Iroquois. Mr. Hewitt has undertaken to subject, so far as possible, this text material to a careful literary and historical analysis and also to a thorough grammatic and lexic criticism, in order to restore as far as the evidence thus secured will warrant, these rituals and chants and set addresses to the earlier forms which were probably used when the League of the Iroquois was instituted in the closing decades of the sixteenth century. This work is necessarily tedious and slow but is of supreme necessity. The results thus far are highly gratifying.

In June, 1924, Mr. Hewitt visited the Six Nations of Iroquois dwelling near Brantford, Ontario, Canada; the Onondaga dwelling near Syracuse, N. Y.; the Tonawanda dwelling near Akron, N. Y.; the Tuscarora dwelling near Sanborn, N. Y. His object on this trip was to obtain a better knowledge of the music of the ritual chants of the Condolence and Installation Council. He also secured a quantity of purple wampum which is used in these league rituals and which has now become so scarce that its cost is well-nigh prohibitive.

Mr. Hewitt was also able to secure from the very few persons who still retain some definite knowledge of the principles and institutions of the league additional interpretative and confirmatory information concerning certain critical passages in the native texts which he recorded in former field trips.

Mr. Francis La Flesche, ethnologist, gave most of his time to the assembling of his notes on the child-naming rites and ceremonies of the Osage Indians. These ancient rites, with their ceremonies, are now practically obsolete, and it was fortunate that Mr. La Flesche succeeded in securing two of the remaining versions. The first was obtained from Wa-xthi′-zhi, a member of the I^{n}-gtho^{n}′-ga or Puma gens. This version will form the first part of the volume on this subject.

The other version is that used by the Tsi′-zhu Wa-shta-ge, Peacemaker, gens. It was with considerable difficulty obtained from old Sho^{n}′-ge-mo^{n}-i^{n}, a member of the gens, who was very conservative and opposed to having any of the tribal rites go to strangers. Since the recording of these ancient rites that had been transmitted through many generations, both these No^{n}′-ho^{n}-zhi^{n}-ga, Wa-xthi′-zhi and Sho^{n}′-ge-mo^{n}-i^{n}, have died, and it is now doubtful if any member of the tribe could be found who is able to recite the rituals and go through the ceremonial forms in their entirety.

Tsi′-zhu Wa-shta-ge version will form the second part of the volume, now nearing completion, which is to be called "Osage Child Naming Rites."

Mr. W. E. Myer, special archeologist, on his return from field work in Tennessee, took up the preparation of his report on the remains of the great prehistoric Indian settlement known as the Great Mound Group in Cheatham County, Tenn., a preliminary account of which was given in last year's report. This town is situated on the Harpeth River near Kingston Springs and is found in two clusters about a mile apart in the bend of the Harpeth River, covering about 500 acres. The fortification of the Great Mound Group was one of the finest prehistoric structures for defense made by the Indians of Tennessee.

Nearly all the lower river bend, called the "Mound Bottom" by the local people, contains evidences of walls, many of which have disappeared by long cultivation of the soil. Mr. Myer was not able to determine the age of these mounds, but buildings which they represent were undoubtedly destroyed before the coming of the white people.

One of the most interesting results of the summer's work was the excavation of a small mound on the Denny farm at Goodlettsville, Sumner County, Tenn., the relics from this mound showing that the inhabitants of this site belonged to a culture quite unlike that of much of the surrounding region in the valley of the Cumberland.

Mr. Myer also made studies in the southern part of Tennessee in Lincoln and Moore Counties and made a map of a hitherto undescribed mound group on Elk River.

SPECIAL RESEARCHES

During the summer of 1923 Miss Frances Densmore visited the Makah Indians at Neah Bay, Wash., and recorded their songs. Neah Bay is near the end of Cape Flattery, but the coast is so mountainous that it is reached only by boat. At the time of Miss Densmore's visit there was only one passenger boat a week to this village. The principal industry of the Indians is salmon fishing. The purpose of this trip was to observe the music of Indians who live beside the ocean and to compare the music with that of tribes living on the mountains, plains, and desert. As a result of the comparison it was found that the music of the Makah resembles that of the Ute, Papago, and Yuma more than it resembles that of the Chippewa, Sioux, and Pawnee. This is general observation, the detailed comparison being unfinished. Three instances are as follows: (1) The Makah Indians use a "high drone," or sustained tone held by two or three women's voices, while the others sing the melody. This was heard among the Papago in southern Arizona and is found in certain parts of Asia. This suggests a cultural evidence that the Indians migrated from Asia and down the Pacific coast, the use of the drone being more pronounced among the Makah than among the Papago; (2) the Makah Indians have a considerable number of "non-harmonic" songs to which the term "key" can not properly be applied. These were found in southern Arizona but not in the plains region; (3) the Makah songs concerning the whale are marked by a very small compass and small intervals. The Ute songs concerning the bear are also characterized by small intervals, but the compass is not particularly small. The Makah songs recorded were of several classes, including songs of the whale legends and whaling expedi-

tions, songs of the potlatch and various social dances, songs connected with contests of physical strength, "gratitude songs," which were sung by individuals at feasts, lullabies for children, courting songs, and the songs of wedding festivities.

Dances and gatherings of the tribe were attended; numerous specimens illustrating the culture of the people were collected; the singers and environment were photographed; and about 30 specimens of plants were collected, with a description of their economic uses.

While in Washington, D. C., Miss Densmore arranged in a catalogue list 368 songs awaiting publication, and arranged in the proper order for publication all her material on Pawnee, Papago, Yuma, Cocopa, and Mohave music. Four manuscripts were submitted during the year, with the titles "Cocopa and Mohave Dance Songs," "Dance Songs and Flute Music of the Yuma," "Whaling Songs, Dream Songs, and Legend Songs of the Makah," and "Potlatch Songs of the Makah." These comprised, in addition to the text, 87 songs, with phonograph records, musical transcriptions, and analyses.

EDITORIAL WORK AND PUBLICATIONS

The editing of the publications of the bureau was continued through the year by Mr. Stanley Searles, editor, assisted by Mrs. Frances S. Nichols, editorial assistant. The status of the publications is presented in the following summary:

PUBLICATIONS ISSUED

Bulletin 79. Blood Revenge, War, and Victory Feasts Among the Jibaro Indians of Eastern Ecuador (Karsten). viii, 94 pp., 10 pls.

Bulletin 80. Mandan and Hidatsa Music (Densmore). xx, 192 pp., 19 pls., 6 figs.

Bulletin 81. Excavations in the Chama Valley, New Mexico (Jeancon). ix, 80 pp., 65 pls., 38 figs.

List of publications of the Bureau of American Ethnology. 45 pp.

PUBLICATIONS IN PRESS OR IN PREPARATION

Thirty-eighth Annual Report. Accompanying paper: An Introductory Study of the Arts, Crafts, and Customs of the Guiana Indians (Roth).

Thirty-ninth Annual Report. Accompanying paper: The Osage Tribe: The Rite of Vigil (La Flesche).

Fortieth Annual Report. Accompanying papers: The Mythical Origin of the White Buffalo Dance of the Fox Indians; The Autobiography of a Fox Indian Woman; Notes on Fox Mortuary Customs and Beliefs; Notes on the Fox Society Known as "Those Who Worship the Little Spotted Buffalo"; the Traditional Origin of the Fox Society Known as "The Singing Around Rite" (Michelson).

Forty-first Annual Report. Accompanying paper: Salish Basketry (Boas).

Forty-second Annual Report. Accompanying paper: Social Organization and Social Usages of the Indians of the Creek Confederacy (Swanton).

Bulletin 78. Handbook of the Indians of California (Kroeber).
Bulletin 82. Two Prehistoric Villages in Middle Tennessee (Myer).

DISTRIBUTION OF PUBLICATIONS

The distribution of publications has been continued under the immediate charge of Miss Helen Munroe, assisted by Miss Emma B. Powers. Publications were distributed as follows:

Report volumes and separates	2,058
Bulletins and separates	11,384
Contributions to North American ethnology	10
Miscellaneous publications	511
	13,963

As compared with the fiscal year ending June 30, 1923, there was a decrease of 3,731 publications distributed, due to the fact that no report volumes were issued during the year, whereas two reports were published in the preceding fiscal year.

ILLUSTRATIONS

Mr. DeLancey Gill, illustrator, with the assistance of Mr. Albert E. Sweeney, continued the preparation of the illustrations of the bureau. A summary of this work follows:

Drawings for publications	138
Photographic prints retouched for engraving	85
Negatives prepared	372
Films developed and printed from field exposures (rolls)	24
Photographic prints for distribution and office use	733

The work of reclassification of negatives has progressed satisfactorily. As a prelude to a new catalogue of the large collection of negatives, this work will be of lasting value. About 4,000 negatives were identified and rejacketed, but much yet remains to be done.

LIBRARY

The reference library continued under the immediate care of Miss Ella Leary, librarian, assisted by Mr. Thomas Blackwell.

During the year 560 books were accessioned. Of these 82 were acquired by purchase, 253 by gift and exchange, and 225 by binding of periodicals. The current periodicals annually received number about 975, of which 37 are by subscription, the remainder being received through exchange. The library has also received 225 pamphlets. The aggregate number of books in the library at the close of the year was 25,621, of pamphlets about 15,325.

During the year many students not connected with the Smithsonian Institution have applied to the library for books. The library

was used also by the Library of Congress and officers of the executive departments, and out of town students have made use of the library through frequent loans.

Conditions of crowding on the book shelves are now acute in many places in the stacks. Many volumes received by the library not pertaining to anthropology were transferred to the library of the Smithsonian Institution.

COLLECTIONS

The following collections, purchased or acquired by members of the bureau or by those detailed in connection with its researches, have been transferred to the United States National Museum:

70367. Collection of about 90 specimens of picture pottery from the Mimbres Valley, N. Mex.

70553. Blanket on which is woven an elaborate representation of the Yeibichi dance of the Navaho Indians, presented to the bureau by Mr. Chee Dodge, St. Michael's, Ariz.

71026. Collection of archeological specimens made by the late John L. Baer during the summer of 1923 in the Susquehanna Valley region.

71278. California Mission Indian water basket collected by J. P. Harrington during the summer of 1922.

71347. Collection of archeological specimens secured in Tennessee and South Dakota by the late William E. Myer.

71430. Collection of archeological specimens from Pipe Shrine House in the Mesa Verde National Park, Colo.

71614. Collection of Indian implements and fossil animals found in Garrard County, Ky., along the Old Wilderness Trail, and presented to the bureau by Mrs. S. H. Burnside.

71691. Four prehistoric objects presented to the bureau, through the late W. E. Myer, by J. G. Braecklein.

71692. Three separate lots of stone implements from prehistoric village sites near Goodlettsville, Tenn., presented to the bureau through the late W. E. Myer, by a Mr. Meadow, John Bell Cartwright, and Capt. James Roscoe.

71694. Three lots of archeological specimens presented to the bureau, through the late W. E. Myer, by C. O. Chapman and A. B. Moore, Mrs. Lee Colin, and A. T. Sweet.

71697. Collection of archeological specimens from the Painted Kiva House, Mesa Verde National Park, Colo.

PROPERTY

Furniture and office equipment were purchased to the amount of $76.29.

MISCELLANEOUS

The correspondence and other clerical work of the office has been conducted by Miss May S. Clark, clerk to the chief. Miss Julia S. Atkins, stenographer and typewriter, assisted the various members

of the staff. Mr. Anthony W. Wilding, typist, has been engaged in copying manuscripts and in various duties connected with the office of the chief.

Mr. W. E. Myer, special archeologist, died December 2, 1923.

Respectfully submitted.

J. Walter Fewkes, *Chief.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 5

REPORT ON THE INTERNATIONAL EXCHANGES

SIR: I have the honor to submit the report on the operations of the International Exchange Service for the fiscal year ended June 30, 1924.

Congress appropriated $43,000 for the support of the service during the year, $2,000 less than the previous appropriation. On the basis of the previous year's business this reduced amount would have been sufficient for the needs of the service. Toward the middle of the fiscal year, however, the exchanges had increased to such an extent that it was necessary to send shipments to foreign countries at less frequent intervals, in order to reduce the expense incurred for freight, so as to avoid a deficit. Near the close of the year it was found possible to return to the Institution's practice of making shipments to all foreign countries at intervals not exceeding a month. In addition to the above amount, Congress appropriated for the exchanges $200 for printing and binding. The repayments from departmental and various other establishments aggregated $5,202.24, making the total resources available for carrying on the system of exchanges during the year $48,402.24.

The total number of packages passing through the service during the year was 460,658, an increase over the number for the preceding year of 82,832. The weight of these packages was 567,107 pounds, an increase of 74,291. Much of this increase was due to the receipt of a large number of publications from establishments in the United States for transmission to the universities and colleges in Japan that lost their libraries during the recent earthquake.

The publications sent and received by the Exchange Service are classified under three heads: Parliamentary documents, departmental documents, and miscellaneous scientific and literary publications. The term "parliamentary documents," as here used, refers to publications set aside by act of Congress for exchange with foreign governments, and includes not only documents printed by order of either House of Congress, but also copies of each publication issued by any department, bureau, commission, or officer of the Government. Governments to which this class of publications are forwarded send to this country in exchange copies of their own official

documents for deposit in the Library of Congress. The term "departmental documents" embraces publications delivered at the Institution by the various governmental departments, bureaus, or commissions for distribution to their correspondents abroad. Publications received in return are deposited in the various departmental libraries. "Miscellaneous scientific and literary publications" are received chiefly from learned societies, universities, colleges, scientific institutions, and museums in the United States for transmission to similar establishments in all parts of the world.

The number and weight of the packages of different classes are indicated in the following table:

	Packages		Weight	
	Sent	Received	Sent	Received
			Pounds	*Pounds*
United States parliamentary documents sent abroad	176,290		83,517	
Publications received in return for parliamentary documents		4,867		9,745
United States departmental documents sent abroad	134,401		180,547	
Publications received in return for departmental documents		7,882		24,057
Miscellaneous scientific and literary publications sent abroad	107,034		195,295	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		30,184		73,946
	417,725	42,933	459,359	107,748
Grand total	460,658		567,107	

As mentioned in previous reports, the disparity between the number of publications transmitted abroad and those received in return is not as great as appears from the above figures. Packages sent abroad contain in many instances only a single publication, while those received in return often comprise several volumes. Furthermore, some foreign establishments send their publications directly to their destinations in this country by mail instead of through exchange channels.

During the year the State Department notified the Institution that the Government of Hungary had adhered to the two exchange conventions concluded at Brussels in 1886 and had established the Hungarian Libraries Board at Budapest to carry out the provisions of those conventions. The board was not fully established at the close of the year, but will be ready to assume its duties as the Hungarian Exchange Agency about October 1, 1924, when the agency in Budapest conducted by the Institution for many years will be discontinued. Dr. Julius Pikler, who has been the Smithsonian agent since July 1, 1906, has carried on the work to the entire

satisfaction of the Institution, and I desire to express here appreciation of his faithful and efficient service during his connection with this office.

The Institution was advised through diplomatic channels that the Governments of the Dominican Republic, Hungary, Latvia, and the Free City of Danzig had adhered to the two exchange conventions concluded at Brussels March 15, 1886.

Toward the close of the fiscal year the librarian of the Storting advised the Institution that the Norwegian depository of United States official documents had been changed from the Stortingets Bibliotek to the Universitets Bibliotek, Christiania.

The Japanese Association of the League of Nations submitted to this country through the Embassy of Japan in Washington an appeal for books for replenishing the libraries of Japanese universities and colleges which were destroyed by the earthquake. The association stated that that disaster wiped out huge collections of books in many libraries, including the collection of 700,000 volumes in the library of the Imperial University of Tokyo. The appeal was heeded by many American establishments and thousands of publications were forwarded to the Smithsonian Institution for transmission to Japan through the International Exchange Service.

From time to time some of the establishments that make use of the exchange service in the distribution of their publications abroad add to their announcements a word of appreciation. During the year a number of such gratifying expressions have been received, particularly from the Argentine Republic, England, Germany, and this country.

During the year 2,464 boxes were used in forwarding exchanges to foreign agencies for distribution, being an increase of 241 over the number for the preceding 12 months. Of the total number of boxes sent abroad, 289 contained full sets of United States official documents for foreign depositories, and 2,175 included departmental and other publications for depositories of partial sets and for other correspondents. In addition to the packages sent abroad in boxes, the exchange service mailed directly to their destinations during the year about 40,000 packages. While it is the practice of the service to send exchanges by freight to foreign agencies for distribution, quite a number of packages are received for remote places which can not well be reached through any of the agencies, and these packages are forwarded by mail. Furthermore, owing to the high ocean freight rates it often happens that it is cheaper to mail packages to some countries than to pack them in boxes and ship them by freight.

The number of boxes sent to each country is given in the following table:

Consignments of exchanges for foreign countries

Country	Number of boxes	Country	Number of boxes
Argentine Republic	44	Japan	262
Austria	55	Latvia	14
Belgium	65	Lithuania	9
Bolivia	2	Mexico	30
Brazil	34	Netherlands	65
British Colonies	3	New South Wales	29
Bulgaria	4	New Zealand	23
Canada	30	Norway	42
Chile	22	Peru	11
China	75	Poland	45
Colombia	16	Portugal	16
Costa Rica	9	Queensland	15
Cuba	5	Rumania	13
Czechoslovakia	64	Russia	72
Danzig	2	South Australia	18
Denmark	37	Spain	33
Egypt	7	Sweden	68
Esthonia	22	Switzerland	61
Finland	11	Tasmania	6
France	185	Union of South Africa	32
Germany	292	Uruguay	12
Great Britain and Ireland	332	Venezuela	10
Greece	11	Victoria	39
Hungary	47	Western Australia	6
India	50	Yugoslavia	15
Italy	92		
Jamaica	2		2,464

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENTAL DOCUMENTS

In accordance with the terms of a convention concluded at Brussels March 15, 1886, and under authority granted by Congress in resolutions approved March 2, 1867, and March 2, 1901, 59 full sets of United States official documents and 38 partial sets are now sent through the Exchange Service regularly to depositories abroad. The Ministry of Finance, Government of Northern Ireland, Belfast; State Library, Reval, Esthonia; and the library of the League of Nations, located at Geneva, Switzerland, have lately been added to the list of those receiving full sets. The number of full and partial sets of governmental documents forwarded to foreign depositories is 97. The total number provided by law for this purpose and for the Library of Congress is 100.

The convention concluded at Brussels in 1886 provided for the international exchange of official documents and scientific and literary publications. That convention was ratified by the United States, Belgium, Brazil, Italy, Portugal, Serbia, Spain, and Switzerland. Since the ratification of the Brussels convention a number of coun-

tries have adhered thereto. The names of the countries, together with the dates of their adherence, follow: Argentine Republic, 1889; Paraguay, 1889; Uruguay, 1889; Poland, 1920; Czechoslovakia, 1921; Rumania, 1923; Dominican Republic, 1923; Hungary, 1923; and Danzig, 1924.

In addition to the governments that have formally joined the convention, many countries exchange their official documents with the United States Government as will be noted from the lists given below:

DEPOSITORIES OF FULL SETS

ARGENTINE REPUBLIC: Ministerio de Relaciones Exteriores, Buenos Aires.
AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.
AUSTRIA: Bundesamt für Statistik, Schwarzenbergstrasse 5, Vienna I.
BADEN: Universitäts-Bibliothek, Freiburg. (Depository of the State of Baden.)
BAVARIA: Staats-Bibliothek, Munich.
BELGIUM: Bibliothèque Royale, Brussels.
BRAZIL: Bibliotheca Nacional, Rio de Janeiro.
BUENOS AIRES: Biblioteca de la Universidad Nacional de La Plata. (Depository of the Province of Buenos Aires.)
CANADA: Library of Parliament, Ottawa.
CHILE: Biblioteca del Congreso Nacional, Santiago.
CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
COLOMBIA: Biblioteca Nacional, Bogotá.
COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CUBA: Secretaría de Estado (Asuntos Generales y Canje Internacional). Habana.
CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
DENMARK: Kongelige Bibliotheket, Copenhagen.
ENGLAND: British Museum, London.
ESTHONIA: Riigiraamatukogu, Reval.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Deutsche Reichstags-Bibliothek, Berlin.
GLASGOW: City Librarian, Mitchell Library, Glasgow.
GREECE: Bibliothèque Nationale, Athens.
HUNGARY: Hungarian House of Delegates, Budapest.
INDIA: Imperial Library, Calcutta.
IRISH FREE STATE: National Library of Ireland, Dublin.
ITALY: Biblioteca Nazionale Vittorio Emanuele, Rome.
JAPAN: Imperial Library of Japan, Tokyo.
LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
MANITOBA: Provincial Library, Winnipeg.
MEXICO: Biblioteca Nacional, Mexico.
NETHERLANDS: Bibliotheek van de Tweede Kamer der Staten-Generaal, The Hague.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
NEW ZEALAND: General Assembly Library, Wellington.
NORTHERN IRELAND: Ministry of Finance, Belfast.

NORWAY: Universitets-Bibliotek, Christiania. (Depository of the Government of Norway.)
ONTARIO: Legislative Library, Toronto.
PARIS: Préfecture de la Seine.
PERU: Biblioteca Nacional, Lima.
POLAND: Bibliothèque du Ministère des Affaires Etrangères, Warsaw.
PORTUGAL: Bibliotheca Nacional, Lisbon.
PRUSSIA: Preussische Staatsbibliothek, Berlin, N. W. 7.
QUEBEC: Library of the Legislature of the Province of Quebec, Quebec.
QUEENSLAND: Parliamentary Library, Brisbane.
RUSSIA: Shipments temporarily suspended.
SAXONY: Landesbibliothek, Dresden-N.
SOUTH AUSTRALIA: Parliamentary Library, Adelaide.
SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.
SWITZERLAND: Library of the League of Nations, Palace of Nations, Quai de Leman, Geneva.
TASMANIA: Parliamentary Library, Hobart.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
WURTTEMBERG: Landesbibliothek, Stuttgart.
YUGOSLAVIA: Ministère des Affaires Étrangères, Belgrade.

DEPOSITORIES OF PARTIAL SETS

ALBERTA: Provincial Library, Edmonton.
ALSACE-LORRAINE: Bibliothèque Universitaire et Régionale de Strasbourg, Strasbourg.
BOLIVIA: Ministerio de Colonización y Agricultura, La Paz.
BRAZIL: Bibliotheca da Assemblea Legislativa do Estado do Rio de Janeiro, Nictheroy.
BREMEN: Senatskommission für Reichs- und Auswärtige Angelegenheiten.
BRITISH COLUMBIA: Legislative Library, Victoria.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
BULGARIA: Ministère des Affaires Étrangères, Sofia.
CEYLON: Colonial Secretary's Office (Record Department of the Library), Colombo.
ECUADOR: Biblioteca Nacional, Quito.
EGYPT: Bibliothèque Khédiviale, Cairo.
FINLAND: Central Library of the State, Helsingfors.
GUATEMALA: Secretary of the Government, Guatemala.
HAITI: Secrètaire d'État des Relations Extérieures, Port-au-Prince.
HAMBURG: Senatskommission für die Reichs- und Auswärtigen Angelegenheiten.
HESSE: Landesbibliothek, Darmstadt.
HONDURAS: Secretary of the Government, Tegucigalpa.
JAMAICA: Colonial Secretary, Kingston.
LATVIA: Ministry of Foreign Affairs, Riga.
LIBERIA: Department of State, Monrovia.

LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.
LÜBECK: President of the Senate.
MADRAS, PROVINCE OF: Chief Secretary to the Government of Madras, Public Department, Madras.
MALTA: Minister for the Treasury, Valetta.
NEW BRUNSWICK: Legislative Library, Fredericton.
NEWFOUNDLAND: Colonial Secretary, St. John's.
NICARAGUA: Superintendente de Archivos Nacionales, Managua.
NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
PANAMA: Secretaría de Relaciones Exteriores, Panama.
PARAGUAY: Oficina General de Inmigración, Asuncion.
PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.
RUMANIA: Academia Romana, Bukharest.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SASKATCHEWAN: Government Library, Regina.
SIAM: Department of Foreign Affairs, Bangkok.
STRAITS SETTLEMENTS: Colonial Secretary, Singapore.
UNITED PROVINCES OF AGRA AND OUDH: Undersecretary to Government, Allahabad.
VIENNA: Bürgermeister-Amt der Stadt Wien.

INTERPARLIAMENTARY EXCHANGE OF OFFICIAL JOURNAL

The interparliamentary exchange is separate from the exchange of official documents above referred to and is carried on by the Smithsonian Institution in behalf of the United States Government in accordance with a resolution of Congress approved March 4, 1909. This resolution accords with the terms of the second convention concluded at Brussels March 15, 1886, to which the United States was one of the signatories, providing for the immediate exchange of the Official Journal.

During the year the immediate exchange has been entered into with Haiti, Latvia, and Norway. The names of the establishments to which the daily issue of the Congressional Record is mailed are given in the following list:

ARGENTINE REPUBLIC: Biblioteca del Congreso Nacional, Buenos Aires.
AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.
AUSTRIA: Bibliothek des Nationalrates, Wien I.
BADEN: Universitäts-Bibiliothek, Heidelberg.
BELGIUM: Bibliothèque de la Chambre des Représentants, Brussels.
BOLIVIA: Cámara de Diputados, Congreso Nacional, La Paz.
BRAZIL: Bibliotheca do Congresso Nacional, Rio de Janeiro.
BUENOS AIRES: Biblioteca del Senado de la Provincia de Buenos Aires, La Plata.
CANADA:
Library of Parliament, Ottawa.
Clerk of the Senate, Houses of Parliament, Ottawa.
COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CUBA:
Biblioteca de la Cámara de Representantes, Habana.
Biblioteca del Senado, Habana.

CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
DENMARK: Rigsdagens Bureau, København.
ESTHONIA: Riigiraamatukogu, Reval.
FRANCE:
Bibliothèque de la Chambre des Députés, au Palais Bourbon, Paris.
Bibliothèque du Sénat, au Palais du Luxembourg, Paris.
GREAT BRITAIN: Library of the Foreign Office, Downing Street, London, S. W. 1.
GREECE: Library of Parliament, Athens.
GUATEMALA: Biblioteca de la Oficina Internacional Centro-Americana, 8a Calle Poniente No. 1, Ciudad de Guatemala.
HAITI: Secrètaire d'État des Relations Extérieures, Port-au-Prince.
HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.
HUNGARY: Bibliothek des Abgeordnetenhauses, Budapest.
ITALY:
Biblioteca della Camera dei Deputati, Palazzo di Monte Citorio, Rome.
Biblioteca del Senato del Regno, Palazzo Madama, Rome.
LATVIA: Library of the Saeima, Riga.
LIBERIA: Department of State, Monrovia.
NEW SOUTH WALES: Library of Parliament, Sydney.
NEW ZEALAND: General Assembly Library, Wellington.
NORWAY: Stortingets Bibliotek, Christiania.
PERU: Cámara de Diputadoes, Congreso Nacional, Lima.
POLAND: Monsieur le Ministre des Affaires Étrangères, Warsaw.
PORTUGAL: Bibliotheca do Congresso da Republica, Lisbon.
PRUSSIA: Bibliothek des Abgeordnetenhauses, Prinz-Albrechtstrasse 5, Berlin, S. W. 11.
QUEENSLAND: The Chief Secretary's Office, Brisbane.
RUMANIA: Bibliothèque de la Chambre des Députés, Bukharest.
SPAIN:
Biblioteca del Congreso de los Diputados, Madrid.
Biblioteca del Senado, Madrid.
SWITZERLAND:
Bibliothèque de l'Assemblée Fédérale Suisse, Berne.
Library of the League of Nations, Geneva.
TRANSVAAL: State Library, Pretoria.
UNION OF SOUTH AFRICA: Library of Parliament, Cape Town.
URUGUAY: Biblioteca de la Cámara de Representantes, Montevideo.
VENEZUELA: Cámara de Diputados, Congreso Nacional, Caracas.
WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.
YUGOSLAVIA: Library of the Skupshtina, Belgrade.

It will be noted from the above list that there are at present 41 different foreign States or Provinces with which the immediate exchange of the Official Journal is carried on. To some of the countries two copies of the Congressional Record are forwarded, one to the upper, and one to the lower house of Parliament. The total number of the Records transmitted is 47. The number provided by law for this exchange is 100.

FOREIGN EXCHANGE AGENCIES

ALGERIA, *via* France.
ANGOLA, *via* Portugal.
ARGENTINE REPUBLIC: Comisión Protectora de Bibliotecas Populares, Calle Córdoba 931, Buenos Aires.

AUSTRIA: Bundesamt für Statistik, Schwarzenbergstrasse 5, Vienna I.
AZORES, *via* Portugal.
BELGIUM: Service Belge des Échanges Internationaux, Rue des Longs-Chariots 46, Brussels.
BOLIVIA: Oficina Nacional de Estadística, La Paz.
BRAZIL: Serviço de Permutações Internacionaes, Bibliotheca Nacional, Rio de Janeiro.
BRITISH COLONIES: Crown Agents for the Colonies, London.
BRITISH GUIANA: Royal Agricultural and Commercial Society, Georgetown.
BRITISH HONDURAS: Colonial Secretary, Belize.
BULGARIA: Institutions Scientifiques de S. M. le Roi de Bulgarie, Sofia.
CANARY ISLANDS, *via* Spain.
CHILE: Servicio de Canjes Internacionales, Biblioteca Nacional, Santiago.
CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
CHOSEN: Government General, Keijo.
COLOMBIA: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogotá.
COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CZECHOSLOVAKIA: Service Tchécoslovaque des Échanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1–79.
DANZIG: Stadtbibliothek, Danzig.
DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.
DUTCH GUIANA: Surinaamsche Koloniale Bibliotheek, Paramaribo.
ECUADOR: Ministerio de Relaciones Exteriores, Quito.
EGYPT: Government Publications Office, Printing Department, Bulaq, Cairo.
ESTHONIA: State Library, Reval.
FINLAND: Delegation of the Scientific Societies of Finland, Helsingfors.
FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.
GERMANY: Amerika-Institut, Universitätstrasse 8, Berlin, N. W. 7.
GREAT BRITAIN AND IRELAND: Messrs. Wheldon & Wesley, 2, 3, and 4 Arthur St., New Oxford St., London, W. C. 2.
GREECE: Bibliothèque Nationale, Athens.
GREENLAND, *via* Denmark.
GUATEMALA: Instituto Nacional de Varones, Guatemala.
HAITI: Secrètaire d'État des Relations Extérieures, Port au Prince.
HONDURAS: Biblioteca Nacional, Tegucigalpa.
HUNGARY: Hungarian Libraries Board, Budapest.
ICELAND, via Denmark.
INDIA: Superintendent of Stationery, Bombay.
ITALY: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome,
JAMAICA: Institute of Jamaica, Kingston.
JAPAN: Imperial Library of Japan, Tokyo.
JAVA, *via* Netherlands.
LATVIA: Ministry of Foreign Affairs, Riga.
LIBERIA: Bureau of Exchanges, Department of State, Monrovia.
LITHUANIA: Sent by mail.
LOURENÇO MARQUEZ, *via* Portugal.
LUXEMBURG, *via* Belgium.
MADAGASCAR, *via* France.

MADEIRA, *via* Portugal.
MOZAMBIQUE, *via* Portugal..
NETHERLANDS: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Académie Technique, Delft.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
NEW ZEALAND: Dominion Museum, Wellington.
NICARAGUA: Ministerio de Relaciones Exteriores, Managua.
NORWAY: Universitets-Bibliotek, Christiania.
PANAMA: Secretaría de Relaciones Exteriores, Panama.
PARAGUAY: Servicio de Canje Internacional de Publicaciones, Secciones Consular y de Comercio, Ministerio de Relaciones Exteriores, Asuncion.
PERU: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.
POLAND: Bibliothèque du Ministère des Affaires Étrangères, Warsaw.
PORTUGAL: Secção de Trocas Internacionaes, Bibliotheca Nacional, Lisbon.
QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.
RUMANIA: Institutul Meteorologic Central, Ministerul Agriculturei, Bukharest.
RUSSIA: Academy of Sciences, Leningrad.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SIAM: Department of Foreign Affairs, Bangkok.
SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.
SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
SUMATRA, *via* Netherlands.
SWEDEN: Kongliga Svenska Vetenskaps Akademien, Stockholm.
SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Berne.
SYRIA: American University of Beirut.
TASMANIA: Secretary to the Premier, Hobart.
TRINIDAD: Royal Victoria Institute of Trinidad and Tobago, Port-of-Spain.
TUNIS, *via* France.
TURKEY: Robert College, Constantinople.
UNION OF SOUTH AFRICA: Government Printing Works, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Carácas.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
YUGOSLAVIA: Académie Royale Serbe des Sciences et des Arts, Belgrade.

Respectfully submitted.

C. G. ABBOT,
Assistant Secretary,
In Charge of Library and Exchanges.

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 6

REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ending June 30, 1924:

The appropriation made by Congress for the regular maintenance of the park was the same as for the preceding year, $125,000. The bill providing for printing and binding, Smithsonian Institution, contained an additional allotment of $300 for the National Zoological Park.

The year has been one of the most successful in the history of the park, both as to care and maintenance of the buildings, grounds, and collections, and in service to the public. In addition to many minor improvements, a new restaurant building has been completed. This was in operation before the close of the year; and the cleanly, roomy, open refreshment room and sanitary serving quarters have been greatly appreciated by visitors. The collection is beyond doubt of far greater value and scientific interest than ever before, and has been kept in excellent condition, with low rate of loss. All previous attendance records have been broken, and a total of 2,442,880 visitors was recorded for the year.

ACCESSIONS

Gifts.—Altogether, 221 animals were presented to the park, or placed on indefinite deposit, during the year. A most notable accession was a fine young Baird's tapir, presented by Mr. M. G. Henery, of Puerto Castillo, Honduras, and obtained through the interest of Dr. Wm. M. Mann. Baird's tapir has always been one of the rarest animals in captivity and the only specimen ever before in the National Zoological Park was a young animal exhibited for a short time 24 years ago. Three species of tapirs are now living in the park, a most unusual record for any zoological garden. Mr. Henery is to be congratulated on his notable achievement in adding this unusual animal to the national collections.

Mr. Victor J. Evans, of Washington, D. C., who has taken a great interest in the National Zoological Park for many years, continued his contributions of carefully selected animals of the rarer and more

unusual varieties. Among the specimens received from him during the last year were such valuable species as the agile gibbon, gelada baboon, Tasmanian devil, crimson-winged paroquet, Australian catbird, and long-necked turtle. Altogether, Mr. Evans contributed 55 animals to the park during the year.

A most interesting collection from Brazil was brought to the park by Dr. W. L. Schurz, commercial attaché, United States Embassy, Rio de Janeiro. This collection included a fine South American bush dog (*Icticyon venaticus*), the first of its kind to be exhibited in the park. There were also an ocelot, capybara, coatimundi, and several birds. The bush dog is an exceedingly rare species in collections.

The Canadian Government, through Hon. J. B. Harkin, Commissioner of Dominion Parks, presented a male yak and two female Rocky Mountain sheep from Banff, Alberta; and the State Fish and Game Commission of Utah, through Hon. D. H. Madsen, contributed four beavers and a notable collection of wild ducks, including six different species.

The complete list of gifts for the year, from 77 individual donors, is as follows:

Mr. E. J. Abernethy, Connelly Springs, N. C., great horned owl.

Capt. Frank Vans Agnew, Peten, Guatemala, ocelot.

Hon. Henry D. Baker, Trinidad, British West Indies, 2 tree porcupines and 2 blue-and-yellow macaws.

Mr. H. S. Barber, Washington, D. C., copperhead.

Mrs. B. W. Barton, Baltimore, Md., cockateel.

Dr. Paul Bartsch, Washington, D. C., chuck-wills-widow and 2 Bahama rock iguanas.

Mr. Oscar E. Bayard, Orlando, Fla., 2 caracaras.

Mr. L. G. Beerbower, Terra Alta, W. Va., great blue heron.

Mr. John M. C. Betts, Takoma Park, Md., 2 alligators.

Mrs. W. O. Biggs, Washington, D. C., ocelot.

Mr. Albert A. Breeden, Manassas, Va., Virginia opossum.

Mrs. C. M. Buck, Washington, D. C., double yellow-head parrot.

Canadian Government, through Hon. J. B. Harkin, yak and 2 Rocky Mountain sheep.

Mrs. E. B. Chapman, Washington, D. C., mallard.

Mr. Austin H. Clark, Washington, D. C., canary.

Mr. G. W. Clarke, Washington, D. C., Cooper's hawk.

Mrs. J. L. Conn, Washington, D. C., orange-winged parrot.

Hon. Calvin Coolidge, White House, Washington, D. C., black bear and peafowl.

Mr. T. E. Counts, Manassas, Va., Virginia opossum.

Mrs. J. H. Cummings, Wilmington, N. C., coachwhip snake, corn snake, and 2 glass snakes.

Mr. Charles F. Denley, Glenmont, Md., 3 vulturine guinea fowls.

Mr. C. S. East, Washington, D. C., copperhead.

Mr. Joseph Edgal, Washington, D. C., 2 domestic rabbits.

Mr. Victor J. Evans, Washington, D. C., agile gibbon, gelada baboon, 2 Tasmanian devils, sulphur-crested cockatoo, Pennant's paroquet, crimson-

winged paroquet, 2 grass paroquets, severe macaw, 2 musk lorikeets, Australian catbird, shining starling, 2 red-faced Gouldian finches, black-faced Gouldian finch, 5 diamond finches, 3 zebra finches, 4 St. Helena waxbills, rosy-rumped finch, 5 chestnut-breasted finches, 2 red-headed finches, 2 paradise whydahs, African wood hoopoe, Australian thick-knee, 2 crowned pigeons, long-necked turtle, stump-tailed lizard, 2 blue-tongued lizards, 4 water dragons, and 4 Australian skinks.

Mr. Edward S. Fuller, Washington, D. C., loon.

Mr. W. B. Gardner, Charleston, W. Va., banded rattlesnake.

Mr. F. W. Goding, Guayaquil, Ecuador, snowy egret.

Mr. C. W. Good, Washington, D. C., muskrat.

Mrs. George W. Harrington, Richmond, Va., patas monkey and white-throated capuchin.

Mrs. A. F. Hassan, Washington, D. C., horned toad.

Mr. T. M. Haston, Davenport, Fla., alligator.

Mr. M. G. Henery, Puerto Castillo, Honduras, Baird's tapir.

Mr. T. P. Lovering, Wilmington, N. C., copperhead and coachwhip snake.

Dr. M. W. Lyon, South Bend, Ind., Franklin's spermophile.

Hon. D. H. Madsen, State Fish and Game Commission, Salt Lake City, Utah, 4 beavers, green-winged teal, shoveller, 2 redheads, 3 mallards, 8 baldpates, and 11 pintails.

Dr. Wm. M. Mann, Washington, D. C., Mexican spider monkey and 2 Honduras squirrels.

Mr. D. W. May, Mayaguez, Porto Rico, 2 Jamaica red-tailed hawks.

Mr. F. H. McHaffie, Wevaco, W. Va., 2 banded rattlesnakes.

Mrs. F. M. McQuade, Washington, D. C., double yellow-head parrot.

Mr. Andrew Miller, Washington, D. C., red-crowned parrot.

Mr. C. E. Mirguet, Rochester, N. Y., banded rattlesnake and 2 blacksnakes.

Mrs. G. W. Morey, Chevy Chase, Md., red-tailed hawk.

Mr. Walter C. B. Morse, Washington, D. C., orange-winged parrot and mealy parrot.

Mrs. W. P. Norfolk, Baltimore, Md., titi monkey.

Mr. Thos. J. Nutt, Somerville, Mass., green guenon.

Mr. Edward O'Connell, Washington, D. C., red fox.

Mr. W. L. O'Neil, Mount Ida, Va., 2 ring-necked pheasants.

Mr. J. Patten, Washington, D. C., woodchuck.

Mr. Jesse Pawling, Washington, D. C., cooter.

Mr. W. Robert Perkins, Washington, D. C., 2 alligators.

Mr. E .R. Picard, Wilmington, N. C., banded rattlesnake.

Mrs. H. E. Read, Washington, D. C., 2 tovi paroquets.

Maj. A. D. Rorex, Portsmouth, N. H., Santo Domingo parrot.

Mr. R. H. Sargent, Washington, D. C., 2 alligators.

Mr. E. S. Schmid, Washington, D. C., barred owl.

Dr. A. H. Schultz, Baltimore, Md., brown pelican.

Mr. W. L. Schurz, Rio de Janeiro, Brazil, bush dog, ocelot, capybara, gray coatimundi, red-billed toucan, red-and-blue-and-yellow macaw, and 3 blue-and-yellow macaws.

Mrs. W. F. Scruggs, Martinsburg, W. Va., Cuban parrot.

Mr. Asa A. Sheetz, Woodstock, Va., rough green snake.

Dr. R. W. Shufeldt and Mr. James S. Jester, Washington, D. C., 2 water snakes and 2 garter snakes.

Mr. J. H. Smith, Washington, D. C., orange-winged parrot.

Messrs. Sneeden and Davis, Wilmington, N. C., king snake, chicken snake, blacksnake, and spreading adder.

Mrs. G. A. Somerville, Washington, D. C., bob white.

Mr. P. C. Standley and Dr. W. M. Mann, Washington, D. C., Allen's opossum, Panama agouti, 10 tovi paroquets, and loggerhead turtle.

Mrs. Robert B. Stiles, Petersburg, Va., white-throated capuchin.

Mrs. W. W. Stuart, Washington, D. C., white-throated capuchin.

Mr. Landon Thomas, Augusta, Ga., blue-and-yellow macaw.

Mr. J. E. Tyler, Washington, D. C., 3 alligators.

Mr. Allen W. Underwood, Washington, D. C., 2 ringed turtledoves.

Mr. Frank Upsham, Washington, D. C., alligator.

Mr. J. S. Warmbath, Washington, D. C., Virginia opossum and 2 great horned owls.

Mrs. Garret Watson, Washington, D. C., double yellow-headed parrot.

Mr. J. E. White, Snowden, N. C., whistling swan.

Mrs. Grace Wilkinson, Washington, D. C., Cuban parrot.

Mr. Charles M. Willoughby, Washington, D. C., 2 European foxes.

Mr. R. W. Wilson, Glen Echo, Md., California coyote.

Mr. E. F. Wood, Washington, D. C., red fox.

Births.—During the year 42 mammals were born and 27 birds were hatched in the park. These records, as in former reports, include only such as are reared to a reasonable age, no account being made in these published statistics of young that live only a few days. Mammals born include: Mexican puma, 2; lion, 2; dingo, 2; gray wolf, 6; Rocky Mountain sheep, 1; mouflon, 1; aoudad, 1; tahr, 2; American bison, 2; reindeer, 2; Japanese deer, 3; hog deer, 2; fallow deer, 2; red deer, 5; guanaco, 1; Trinidad agouti, 3; rhesus monkey, 1; Javan macaque, 1; red kangaroo, 1; rufous-bellied wallaby, 1; brush-tailed rock wallaby, 1. Birds hatched were of the following species: Blue goose, black duck, wood duck, Australian ibis, black-crowned night heron, and grass paroquet.

Twin monkeys were born for the first time in the records of the park, but one of the young lived only a few days. The species was *Macaca rhesus*. The breeding of the blue goose (*Chen cærulescens*) is a notable achievement, of which the keepers in the bird division may well be proud. The young of this bird have never before been reared, and only once before, so far as is known, has the species nested in captivity.

Exchanges.—A number of desirable animals were received in exchange for surplus stock. These included 12 mammals, 60 birds, and 4 reptiles. Among the especially noteworthy accessions in this class are a young black rhinoceros and a leopard from Africa, 5 reindeer from Norway, and 2 San Geronimo harbor seals from Lower California. Birds received in exchange include a kiwi (*Apteryx mantelli*), which, with a number of other rare species, came from the Wellington, New Zealand, Zoological Gardens in exchange for some American animals. There were also received in exchange a trumpeter swan, a wedge-tailed eagle, and numbers of other waterfowl and cage birds.

Purchases.—Only 9 mammals, 81 birds, and 8 reptiles were purchased during the year. Special mention should be made, however, of a pair of Alpine ibex, from Europe, 10 Marquesas Islands doves, 2 bleeding-heart doves, 12 white-cheeked geese, 2 pink-footed geese, 2 Massena quail, and a gannet. All of these unusual species are doing well in the park.

Transfers.—The Biological Survey, United States Department of Agriculture, transferred to the National Zoological Park a number of especially desirable animals taken by field agents of the bureau or seized by United States game wardens in discharge of their duties. Of particular interest during the year were a black bear from Oregon, 2 pacas from Central America, a black-footed ferret from Nebraska, 2 white-cheeked geese from Alaska, 2 whistling and 2 mute swans. Altogether, the Biological Survey contributed 7 mammals and 11 birds during the year.

Deposits.—Among the few animals received on deposit are two parrots rarely shown in this country. These are the Philippine cockatoo and the Philippine green parrot, both new to the records of the park.

SPECIES NEW TO THE COLLECTION

An unusual number of animals new to the park records were received during the year. A list of the 40 species thus exhibited for the first time follows:

Allen's opossum—*Metachirops opossum fuscogriseus.*
California coyote—*Canis ochropus.*
European fox—*Vulpes vulpes.*
Bush dog—*Icticyon venaticus.*
San Geronimo harbor seal—*Phoca richardii geronimensis.*
Franklin's spermophile—*Citellus franklinii.*
Tree porcupine—*Coendou prehensilis.*
Gray titi monkey—*Callicebus gigot.*
Agile gibbon—*Hylobates lar.*
Alpine ibex—*Capra ibex.*
Black rhinoceros—*Diceros bicornis.*
White-cheeked goose—*Branta canadensis occidentalis.*
Pink-footed goose—*Anser brachyrhynchus.*
Jamaica redtail—*Buteo borealis jamaicensis.*
Vulturine guinea fowl—*Acryllium vulturinum.*
Pukeko—*Porphyrio stanleyi.*
Large-billed thick-knee—*Burhinus magnirostris.*
Philippine cockatoo—*Kakatoe hæmaturopygia.*
Crimson-winged parrot—*Aprosmictus erythropterus.*
Philippine green parrot—*Tanygnathus lucionensis.*
Musk lorikeet—*Glossopsitta concinna.*
Chuck-will's-widow—*Antrostomus carolinensis.*
Morepork owl—*Spiloglaux novæscelandiæ.*
Red-billed toucan—*Ramphastos monilis.*
African wood hoopoe—*Irrisor erythrorhynchus.*

Red-eared bulbul—*Otocompsa jocosa.*
Mistle thrush—*Turdus viscivorus.*
Australian catbird—*Ailuræedus viridis.*
Rosy-rumped waxbill—*Estrilda rhodopyga.*
Red-headed finch—*Amadina erythrocephala.*
Yellow-tailed oriole—*Icterus mesomelas.*
Gray singing finch—*Serinus leucopygius.*
Leclancher's nonpareil—*Passerina leclancheri.*
Bahama rock iguana—*Cyclura rileyi.*
Water dragon—*Physignathus lesueurii.*
Australian skink—*Egerina cunninghamei.*
Western bull snake—*Pituophis catenifer.*
Beaded snake—*Drymobius margaritiferus.*
Mexican musk turtle—*Kinosternon sonoriense.*
Long-necked turtle—*Chelodina longicollis.*

REMOVALS

There were sent away in exchange to other zoological gardens during the year, 75 surplus animals, including 41 mammals, 31 birds, and 3 reptiles. Among these were the following mammals born and reared in the park: European brown bear, 3; raccoon, 4; llama, 1; tahr, 1; yak, 2; Japanese deer, 9; red kangaroo, 1; rufous-bellied wallaby, 3. In addition to these, 26 gray squirrels were sent to Quantico, Va., for stocking the United States Marine Corps reservation at that place, and 21 squirrels were sent to the military reservation at Fort Hayes, Columbus, Ohio.

A number of animals on deposit were returned to owners.

Although the death rate has been held at a normally low mark, there have been, as in all years, a few serious losses of animals. Some records of interest because of the long periods of life in the park are as follows: A sacred ibis (*Threskiornis æthiopicus*) received September 25, 1903, died October 20, 1923, after 20 years and 25 days in the collection. An East African leopard, female, which was presented to the park by Mr. W. N. McMillan, and arrived in Washington December 19, 1909, died 14 years and 4 days later on December 23, 1923. A boatbill heron (*Cochlearius cochlearius*) received September 28, 1910, died on December 11, 1923, after 13 years 2 months and 13 days in the park. A female Mexican agouti (*Dasyprocta mexicana*) received July 7, 1910, died August 28, 1923, having lived in the park for 13 years 1 month and 21 days. A female American elk (*Cervus canadensis*) born in the park on June 5, 1910, died August 10, 1923, at an age of 13 years 2 months and 5 days. A northern wild cat (*Lynx uinta*), male, received January 15, 1912, died 11 years 9 months and 13 days later, on October 28, 1923. A male white stork (*Ciconia ciconia*) received August 12, 1912, died April 26, 1924, after 11 years 8 months and 5 days in the park.

A female tayra (*Tayra barbara*) received September 8, 1914, died on March 20, 1924, from pericarditis, after a life of 9 years 6 months and 12 days in the collection.

Other serious losses by death during the year were a Malay sun bear, congestion of lungs, August 12, 1923; agile gibbon, pneumonia, January 11, 1924; orang-utan, late rickets, February 15, 1924; and a South American tapir, intussusception of small intestine, February 19, 1924.

Post-mortem examinations were made in most cases by the pathological division of the Bureau of Animal Industry; but five examinations were made by Dr. Adolph H. Schultz, of the Carnegie Institution, Laboratory of Embryology; and one was made at St. Elizabeths Hospital, Department of the Interior.

The following list shows the results of autopsies, the cases being arranged by groups:

CAUSES OF DEATH

MAMMALS

Marsupialia: Peritonitis, 1.

Carnivora: Pneumonia, 2; congestion of lungs, 2; enteritis, 1; gastroenteritis, 2; pericarditis, 1; no cause found, 1.

Rodentia: Pneumonia and pericarditis, 1; multiple tumors of lungs, 1; gastroenteritis, 1; roundworm infestation, 1.

Primates: Pneumonia, 1; congestion of lungs, 1; tuberculosis, 2; enteritis, 4; stenosis of intestine, 1; hepatitis, 1; late rickets, 1; no cause found, 2.

Artiodactyla: Gastritis, 1; anemia, 2.

Perissodactyla: Intussusception of small intestine, 1.

Edentata: Gastritis, 1.

BIRDS

Colymbiformes: Aspergillosis, 1.

Ciconiiformes: Diphtheria, 1; internal hemorrhage, 1; anemia, 1.

Anseriformes: Pneumonia, 1; tuberculosis, 1; aspergillosis, 2; colibacillosis, 1.

Galliformes: Colibacillosis, 2; intestinal sarcoma, 1.

Gruiformes: Tuberculosis, 1; enteritis, 2; no cause found, 1.

Charadriiformes: Enteritis, 2; no cause found, 1.

Cuculiformes: No cause found, 1.

Psittaciformes: General cachexia, 1; accident, 2.

Passeriformes: Tæniasis, 1; no cause found, 1.

All specimens of special scientific value needed by the United States National Museum were transferred after death to that institution. These included, during the year, 21 mammals, 50 birds, and 15 reptiles. A number of rare birds' eggs were also sent to the Museum.

Five mammals especially needed by the Carnegie Laboratory of Embryology, Johns Hopkins Medical School, Baltimore, were sent

after death to that institution; and one mammal was sent to St. Elizabeths Hospital, Washington, D. C., for special study of the brain. A few skins of cage birds were saved for the reference collection at the park.

ANIMALS IN THE COLLECTION JUNE 30, 1924

MAMMALS

MARSUPIALIA

Allen's opossum (*Metachirops opossum fuscogriseus*)	1
Virginia opossum (*Didelphis virginiana*)	4
Tasmanian devil (*Sarcophilus harrisii*)	2
Australian opossum (*Trichosurus vulpecula*)	2
Flying phalanger (*Petaurus breviceps*)	7
Brush-tailed rock wallaby (*Petrogale penicillata*)	3
Rufous-bellied wallaby (*Macropus billardierii*)	5
Wallaroo (*Macropus robustus*)	2
Great gray kangaroo (*Macropus giganteus*)	2
Red kangaroo (*Macropus rufus*)	6
Wombat (*Phascolomys mitchelli*)	1

CARNIVORA

Kadiak bear (*Ursus middendorffi*)	2
Alaska Peninsula bear (*Ursus gyas*)	4
Yakutat bear (*Ursus dalli*)	1
Kidder's bear (*Ursus kidderi*)	2
European bear (*Ursus arctos*)	2
Grizzly bear (*Ursus horribilis*)	1
Apache grizzly (*Ursus apache*)	1
Himalayan bear (*Ursus thibetanus*)	1
Black bear (*Ursus americanus*)	3
Cinnamon bear (*Ursus americanus cinnamomum*)	2
Glacier bear (*Ursus emmonsii*)	1
Sloth bear (*Melursus ursinus*)	1
Polar bear (*Thalarctos maritimus*)	2
Dingo (*Canis dingo*)	3
Gray wolf (*Canis nubilus*)	10
Timber wolf (*Canis occidentalis*)	1
Texas red wolf (*Canis rufus*)	1
Coyote (*Canis latrans*)	3
California coyote (*Canis ochropus*)	1
Red fox (*Vulpes fulva*)	4
European fox (*Vulpes vulpes*)	1
Kit fox (*Vulpes velox*)	2
Great-eared fox (*Otocyon megalotis*)	1
Gray fox (*Urocyon cinereoargenteus*)	2
Bush dog (*Icticyon venaticus*)	1
Panda (*Ailurus fulgens*)	1
Raccoon (*Procyon lotor*)	6
Florida raccoon (*Procyon lotor elucus*)	2

CARNIVORA—continued

Gray coatimundi (*Nasua narica*)	2
Red coatimundi (*Nasua nasua*)	1
Kinkajou (*Potos flavus*)	3
Mexican kinkajou (*Potos flavus aztecus*)	1
Tayra (*Tayra barbara*)	1
American badger (*Taxidea taxus*)	1
Florida otter (*Lutra canadensis vaga*)	3
Black-footed ferret (*Mustela nigripes*)	1
Palm civet (*Paradoxurus hermaphroditus*)	2
Aard-wolf (*Proteles cristatus*)	1
Spotted hyena (*Crocuta crocuta*)	1
Striped hyena (*Hyæna hyæna*)	1
African cheetah (*Acinonyx jubatus*)	2
Lion (*Felis leo*)	7
Bengal tiger (*Felis tigris*)	1
Manchurian tiger (*Felis tigris longipilis*)	2
Leopard (*Felis pardus*)	2
Jaguar (*Felis onca*)	1
Brazilian ocelot (*Felis pardalis brasiliensis*)	2
Snow leopard (*Felis uncia*)	1
Mexican puma (*Felis azteca*)	4
Mountain lion (*Felis hippolestes*)	1
Canada lynx (*Lynx canadensis*)	1
Northern wild cat (*Lynx uinta*)	1
Bay lynx (*Lynx rufus*)	3
Clouded leopard (*Neofelis nebulosa*)	1

PINNIPEDIA

California sea lion (*Zalophus californianus*)	2
San Geronimo harbor seal (*Phoca richardii geronimensis*)	1

RODENTIA

Woodchuck (*Marmota monax*)	3
Dusky marmot (*Marmota flaviventris obscura*)	1
Franklin's spermophile (*Citellus franklinii*)	1
Chipmunk (*Eutamias neglectus*)	1
Honduras squirrel (*Sciurus boothiæ*)	2
Albino squirrel (*Sciurus carolinensis*)	2
Bailey's pocket mouse (*Perognathus baileyi*)	1

RODENTIA—continued

American beaver (*Castor canadensis*)	2
Grasshopper mouse (*Onychomys leucogaster*)	3
Muskrat (*Fiber zibethicus*)	1
African porcupine (*Hystrix africæaustralis*)	1
Malay porcupine (*Acanthion brachyurum*)	2
Tree porcupine (*Coendou prehensilis*)	2
Mexican tree porcupine (*Coendou mexicanum*)	1
Coypu (*Myocastor coypus*)	1
Central American paca (*Cuniculus paca virgatus*)	3
Sooty agouti (*Dasyprocta fuliginosa*)	1
Speckled agouti (*Dasyprocta punctata*)	2
Panama agouti (*Dasyprocta punctata isthmica*)	2
Azara's agouti (*Dasyprocta azaræ*)	1
Trinidad agouti (*Dasyprocta rubrata*)	5
Yellow-rumped agouti (*Dasyprocta lucifer cayennæ*)	1
Guinea pig (*Cavia porcellus*)	2
Capybara (*Hydrochærus hydrochæris*)	2

LAGOMORPHA

Domestic rabbit (*Oryctolagus cuniculus*)	17

EDENTATA

Nine-banded armadillo (*Dasypus novemcinctus*)	3

PRIMATES

Gray spider monkey (*Ateles geoffroyi*)	2
Mexican spider monkey (*Ateles neglectus*)	1
White-throated capuchin (*Cebus capucinus*)	6
Weeping capuchin (*Cebus apella*)	2
Brown capuchin (*Cebus fatuellus*)	1
Gelada baboon (*Theropithecus obscurus*)	1
Chacma (*Papio porcarius*)	1
Anubis baboon (*Papio cynocephalus*)	1
East African baboon (*Papio ibeanus*)	1
Mandrill (*Papio sphinx*)	1
Drill (*Papio leucophæus*)	1
Moor macaque (*Cynopithecus maurus*)	1
Barbary ape (*Simia sylvanus*)	2
Japanese macaque (*Macaca fuscata*)	2
Pig-tailed monkey (*Macaca nemestrina*)	1
Burmese macaque (*Macacá andamanensis*)	1
Rhesus monkey (*Macaca rhesus*)	21
Crab-eating macaque (*Macaca irus*)	1
Javan macaque (*Macaca mordax*)	5
Black mangabey (*Cercocebus aterrimus*)	1
Sooty mangabey (*Cercocebus fuliginosus*)	

PRIMATES—continued

Hagenbeck's mangabey (*Cercocebus hagenbecki*)	1
White-collared mangabey (*Cercocebus torquatus*)	1
Patas monkey (*Erythrocebus patas*)	1
Green guenon (*Lasiopyga callitrichus*)	3
Vervet guenon (*Lasiopyga pygerythra*)	1
Mona (*Lasiopyga mona*)	4
Roloway guenon (*Lasiopyga roloway*)	1
Chimpanzee (*Pan satyrus*)	1

ARTIODACTYLA

Wild boar (*Sus scrofa*)	1
Wart hog (*Phacochærus æthiopicus*)	1
Collared peccary (*Pecari angulatus*)	2
Hippopotamus (*Hippopotamus amphibius*)	2
Bactrian camel (*Camelus bactrianus*)	2
Arabian camel (*Camelus dromedarius*)	1
Guanaco (*Lama guanicoe*)	4
Llama (*Lama glama*)	6
Reindeer (*Rangifer tarandus*)	7
Fallow deer (*Dama dama*)	7
Axis deer (*Axis axis*)	3
Hog deer (*Hyelaphus porcinus*)	5
Sambar (*Rusa unicolor*)	2
Barasingha (*Rucervus duvaucelii*)	6
Burmese deer (*Rucervus eldii*)	1
Japanese deer (*Sika nippon*)	13
Red deer (*Cervus elaphus*)	17
Kashmir deer (*Cervus hanglu*)	2
Bedford deer (*Cervus xanthopygus*)	6
American elk (*Cervus canadensis*)	5
Virginia deer (*Odocoileus virginianus*)	6
Panama deer (*Odocoileus chiriquensis*)	1
Black-tailed deer (*Odocoileus columbianus*)	2
Blesbok (*Damaliscus albifrons*)	2
White-tailed gnu (*Connochætes gnou*)	1
Brindled gnu (*Connochætes taurinus*)	1
Lechwe (*Onotragus leche*)	1
Sable antelope (*Egocerus niger*)	1
Indian antelope (*Antilope cervicapra*)	3
Nilgai (*Boselaphus tragocamelus*)	2
East African eland (*Taurotragus oryx livingstonii*)	2
Mountain goat (*Oreamnos americanus*)	5
Tahr (*Hemitragus jemlahicus*)	6
Alpine ibex (*Capra ibex*)	2
Goat (*Capra hircus*)	1
Aoudad (*Ammotragus lervia*)	3
Rocky Mountain sheep (*Ovis canadensis*)	7
Arizona mountain sheep (*Ovis canadensis gaillardi*)	1
Mouflon (*Ovis musimon*)	3
Barbados sheep (*Ovis aries*)	1
Greenland musk-ox (*Ovibos moschatus wardi*)	2
Zebu (*Bos indicus*)	1
Yak (*Poëphagus grunniens*)	4
American bison (*Bison bison*)	15
Indian buffalo (*Bubalis bubalis*)	3

PERISSODACTYLA

Black rhinoceros (*Diceros bicornis*)	1
Malay tapir (*Tapirus indicus*)	1
Brazilian tapir (*Tapirus terrestris*)	1
Baird's tapir (*Tapirella bairdii*)	1
Grant's zebra (*Equus quagga granti*)	1
Grevy's zebra (*Equus grevyi*)	1
Zebra-horse hybrid (*Equus grevyi caballus*)	1
Zebra-ass hybrid (*Equus grevyi asinus*)	1

PROBOSCIDEA

Abyssinian elephant (*Loxodonta africana oxyotis*)	1
Sumatran elephant (*Elephas sumatranus*)	2

BIRDS

RATITÆ

South African ostrich (*Struthio australis*)	5
Somaliland ostrich (*Struthio molybdophanes*)	2
Nubian ostrich (*Struthio camelus*)	1
Rhea (*Rhea americana*)	1
Sclater's cassowary (*Casuarius philipi*)	1
Emu (*Dromiceius novæhollandiæ*)	2
Kiwi (*Apteryx mantelli*)	1

CICONIIFORMES

American white pelican (*Pelecanus erythrorhynchos*)	7
European white pelican (*Pelecanus onocrotalus*)	2
Roseate pelican (*Pelecanus roseus*)	2
Australian pelican (*Pelecanus conspicillatus*)	2
Brown pelican (*Pelecanus occidentalis*)	8
Florida cormorant (*Phalacrocorax auritus floridanus*)	4
Gannet (*Sula bassana*)	2
Great white heron (*Ardea occidentalis*)	2
Great blue heron (*Ardea herodias*)	1
Goliath heron (*Ardea goliath*)	1
American egret (*Casmerodius egretta*)	2
Black-crowned night heron (*Nycticorax nycticorax nævius*)	49
White stork (*Ciconia ciconia*)	1
Black stork (*Ciconia nigra*)	1
Lesser adjutant (*Leptoptilus javanicus*)	1
Wood ibis (*Mycteria americana*)	2
Straw-necked ibis (*Carphibis spinicollis*)	1
Sacred ibis (*Threskiornis æthiopicus*)	2
Black-headed ibis (*Threskiornis melanocephalus*)	3
Australian ibis (*Threskiornis strictipennis*)	4
White ibis (*Guara alba*)	10
Scarlet ibis (*Guara rubra*)	4
European flamingo (*Phœnicopterus roseus*)	1

ANSERIFORMES

Mallard (*Anas platyrhynchos*)	12
Black duck (*Anas rubripes*)	15
Australian black duck (*Anas superciliosa*)	2
Gadwall (*Chaulelasmus streperus*)	2
Falcated duck (*Eunetta falcata*)	2
European widgeon (*Mareca penelope*)	4
Baldpate (*Mareca americana*)	10
Green-winged teal (*Nettion carolinense*)	11
European teal (*Nettion crecca*)	4
Baikal teal (*Nettion formosum*)	6
Blue-winged teal (*Querquedula discors*)	1
Garganey (*Querquedula querquedula*)	6
Shoveller (*Spatula clypeata*)	5
Pintail (*Dafila acuta*)	16
Wood duck (*Aix sponsa*)	10
Mandarin duck (*Dendronessa galericulata*)	12
Canvasback (*Marila valisineria*)	12
European pochard (*Marila ferina*)	3
Redhead (*Marila americana*)	11
Ring-necked duck (*Marila collaris*)	2
Tufted duck (*Marila fuligula*)	1
Lesser scaup duck (*Marila affinis*)	3
Greater scaup duck (*Marila marila*)	9
Rosy-billed pochard (*Metopiana peposaca*)	4
Egyptian goose (*Chenalopex ægyptiacus*)	3
Upland goose (*Chloëphaga leucoptera*)	1
Hawaiian goose (*Nesochen sandvicensis*)	2
Snow goose (*Chen hyperboreus*)	1
Greater snow goose (*Chen hyperboreus nivalis*)	2
Blue goose (*Chen cærulescens*)	10
White-fronted goose (*Anser albifrons*)	2
American white-fronted goose (*Anser albifrons gambeli*)	3
Bean goose (*Anser fabalis*)	2
Pink-footed goose (*Anser brachyrhynchus*)	2
Bar-headed goose (*Eulabeia indica*)	2
Canada goose (*Branta canadensis*)	8
Hutchins's goose (*Branta canadensis hutchinsii*)	6
White-cheeked goose (*Branta canadensis occidentalis*)	14
Cackling goose (*Branta canadensis minima*)	2
Brant (*Branta bernicla glaucogastra*)	10
Barnacle goose (*Branta leucopsis*)	5

ANSERIFORMES—continued

Spur-winged goose (*Plectropterus gambensis*)	1
Muscovy duck (*Cairina moschata*)	1
Pied goose (*Anseranas semipalmata*)	2
Black-bellied tree duck (*Dendrocygna autumnalis*)	5
Eyton's tree duck (*Dendrocygna eytoni*)	4
Mute swan (*Cygnus gibbus*)	4
Trumpeter swan (*Olor buccinator*)	1
Whistling swan (*Olor columbianus*)	1
Black swan (*Chenopsis atrata*)	2

FALCONIFORMES

California condor (*Gymnogyps californianus*)	3
Turkey vulture (*Cathartes aura*)	3
Black vulture (*Coragyps urubu*)	1
King vulture (*Sarcoramphus papa*)	2
Secretary bird (*Sagittarius serpentarius*)	1
Griffon vulture (*Gyps fulvus*)	1
African black vulture (*Torgos tracheliotus*)	1
Cinereous vulture (*Aegypius monachus*)	2
Caracara (*Polyborus cheriway*)	4
Wedge-tailed eagle (*Uroaëtus audax*)	2
Golden eagle (*Aquila chrysaëtos*)	5
White-bellied sea eagle (*Cuncuma leucogaster*)	2
Bald eagle (*Haliæetus leucocephalus*)	7
Alaskan bald eagle (*Haliæetus leucocephalus alascanus*)	3
Broad-winged hawk (*Buteo platypterus*)	1
Red-tailed hawk (*Buteo borealis*)	7
Jamaica redtail (*Buteo borealis jamaicensis*)	1
Sparrow hawk (*Falco sparverius*)	4

GALLIFORMES

Curassow (*Crax daubentoni*)	1
Razor-billed curassow (*Mitu mitu*)	2
Penelope (*Penelope boliviana*)	1
Guan (*Ortalis albiventris*)	1
Chachalaca (*Ortalis vetula*)	1
Vulturine guinea fowl (*Acryllium vulturinum*)	3
Peafowl (*Pavo cristatus*)	18
Peacock pheasant (*Polyplectron bicalcaratum*)	1
Silver pheasant (*Gennæus nycthemerus*)	2
Lady Amherst's pheasant (*Chrysolophus amherstiæ*)	1
Ring-necked pheasant (*Phasianus torquatus*)	10
Bobwhite (*Colinus virginianus*)	2
Gambel's quail (*Lophortyx gambelii*)	1
Valley quail (*Lophortyx californica vallicola*)	1
Scaled quail (*Callipepla squamata*)	5
Massena quail (*Cyrtonyx montezumæ*)	2

GRUIFORMES

East Indian gallinule (*Porphyrio calvus*)	4
Pukeko (*Porphyrio stanleyi*)	1
Black-tailed moor hen (*Microtribonyx ventralis*)	2
American coot (*Fulica americana*)	1
South Island weka rail (*Ocydromus australis*)	3
Short-winged weka (*Ocydromus brachypterus*)	2
Earl's weka (*Ocydromus earli*)	1
Little brown crane (*Grus canadensis*)	4
White-necked crane (*Grus leucauchen*)	1
Indian white crane (*Grus leucogeranus*)	1
Lilford's crane (*Grus lilfordi*)	2
Australian crane (*Grus rubicunda*)	2
Demoiselle crane (*Anthropoides virgo*)	4
Crowned crane (*Balearica pavonina*)	1
Kagu (*Rhynochetos jubatus*)	2

CHARADRIIFORMES

Lapwing (*Vanellus vanellus*)	1
Yellow-wattled lapwing (*Lobivanellus indicus*)	1
Pacific gull (*Gabianus pacificus*)	1
Great black-backed gull (*Larus marinus*)	4
Herring gull (*Larus argentatus*)	3
Silver gull (*Larus novæhollandiæ*)	16
Laughing gull (*Larus atricilla*)	2
Crowned pigeon (*Goura coronata*)	2
Victoria crowned pigeon (*Goura victoria*)	1
Australian crested pigeon (*Ocyphaps lophotes*)	4
Bronze-wing pigeon (*Phaps chalcoptera*)	3
Marquesan dove (*Gallicolumba rubescens*)	12
Bleeding-heart dove (*Gallicolumba luzonica*)	2
Wonga-wonga pigeon (*Leucosarcia picata*)	2
Wood pigeon (*Columba palumbus*)	7
Mourning dove (*Zenaidura macroura*)	3
White-fronted dove (*Leptotila fulviventris brachyptera*)	4
Necklaced dove (*Spilopelia tigrina*)	4
Zebra dove (*Geopelia striata*)	3
Bar-shouldered dove (*Geopelia humeralis*)	1
Inca dove (*Scardafella inca*)	1
Cuban ground dove (*Chæmepelia passerina aflavida*)	1
Green-winged dove (*Chalcophaps indica*)	1
Ringed turtledove (*Streptopelia risoria*)	3
Fruit pigeon (*Lamprotreron superba*)	1

PSITTACIFORMES

Kea (*Nestor notabilis*)	4
Musk lorikeet (*Glossopsitta concinna*)	2

PSITTACIFORMES—continued

Cockateel (*Calopsitta novæhollandiæ*)	2
Roseate cockatoo (*Kakatoe roseicapilla*)	15
Bare-eyed cockatoo (*Kakatoe gymnopis*)	1
Leadbeater's cockatoo (*Kakatoe leadbeateri*)	2
Philippine cockatoo (*Kakatoe hæmaturopygia*)	1
White cockatoo (*Kakatoe alba*)	1
Sulphur-crested cockatoo (*Kakatoe galerita*)	9
Great red-crested cockatoo (*Kakatoe moluccensis*)	1
Cassin's macaw (*Ara auricollis*)	1
Mexican green macaw (*Ara mexicana*)	2
Severe macaw (*Ara severa*)	1
Blue-and-yellow macaw (*Ara ararauna*)	9
Red-and-blue-and-yellow macaw (*Ara macao*)	7
Hahn's macaw (*Diopsittaca hahni*)	1
White-eyed paroquet (*Aratinga leucophthalmus*)	1
Petz's paroquet (*Eupsittula canicularis*)	6
Golden-crowned paroquet (*Eupsittula aurea*)	3
Weddell's paroquet (*Eupsittula weddellii*)	3
Blue-winged parrotlet (*Psittacula passerina*)	14
Golden paroquet (*Brotogeris chrysosema*)	4
Tovi paroquet (*Brotogeris jugularis*)	10
Orange-winged paroquet (*Brotogeris chiriri*)	4
Yellow-naped parrot (*Amazona auropalliata*)	4
Mealy parrot (*Amazona farinosa*)	2
Orange-winged parrot (*Amazona amazonica*)	6
Blue-fronted parrot (*Amazona æstiva*)	1
Red-crowned parrot (*Amazona viridigenalis*)	6
Double yellow-head parrot (*Amazona oratrix*)	10
Yellow-headed parrot (*Amazona ochrocephala*)	4
Festive parrot (*Amazona festiva*)	5
Lesser white-fronted parrot (*Amazona albifrons nana*)	1
Santo Domingo parrot (*Amazona ventralis*)	3
Cuban parrot (*Amazona leucocephala*)	4
Maximilian's parrot (*Pionus maximiliani*)	1
Dusky parrot (*Pionus fuscus*)	2
Blue-headed parrot (*Pionus menstruus*)	2
Amazonian caique (*Pionites xanthomeria*)	5
Lesser vasa parrot (*Coracopsis nigra*)	1

PSITTACIFORMES—continued

Greater vasa parrot (*Coracopsis vasa*)	1
Pennant's paroquet (*Platycercus elegans*)	2
Rosella paroquet (*Platycercus eximius*)	1
Black-tailed paroquet (*Polytelis melanura*)	1
King paroquet (*Aprosmictus cyanopygius*)	1
Crimson-winged paroquet (*Aprosmictus erythropterus*)	
Ring-necked paroquet (*Conurus torquatus*)	1
Nepalese paroquet (*Conurus nepalensis*)	1
Philippine green parrot (*Tanygnathus lucionensis*)	1
Grass paroquet (*Melopsittacus undulatus*)	19

CORACIIFORMES

Giant kingfisher (*Dacelo gigas*)	2
Yellow-billed hornbill (*Lophoceros leucomelas*)	2
Morepork owl (*Spiloglaux novæseelandiæ*)	1
Barred owl (*Strix varia*)	6
Snowy owl (*Nyctea nyctea*)	1
Screech owl (*Otus asio*)	1
Great horned owl (*Bubo virginianus*)	9
Eagle owl (*Bubo bubo*)	1
American barn owl (*Tyto perlata pratincola*)	5
Ariel toucan (*Ramphastos ariel*)	1

PASSERIFORMES

Cock of the rock (*Rupicola rupicola*)	1
Silver-eared hill-tit (*Mesia argentauris*)	1
Red-billed hill-tit (*Liothrix luteus*)	17
Black-gorgeted laughing thrush (*Garrulax pectoralis*)	2
White-eared bulbul (*Otocompsa leucotis*)	3
Red-eared bulbul (*Otocompsa jocosa*)	2
European blackbird (*Turdus merula*)	2
Piping crow shrike (*Gymnorhina tibicen*)	2
Satin bower bird (*Ptilonorhynchus violaccus*)	1
European raven (*Corvus corax*)	1
Australian crow (*Corvus coronoides*)	1
American crow (*Corvus brachyrhynchos*)	1
Magpie (*Pica pica hudsonica*)	2
Yucatan jay (*Cissilopha yucatanica*)	1
Blue jay (*Cyanocitta cristata*)	3
Green jay (*Xanthoura luxuosa*)	3
Australian gray jumper (*Struthidea cinerea*)	1
Starling (*Sturnus vulgaris*)	9

PASSERIFORMES—continued

Shining starling (*Lamprocorax metallicus*)	5
Laysan finch (*Telespyza cantans*)	4
Crimson tanager (*Ramphocelus dimidiatus*)	1
Blue tanager (*Thraupis cana*)	1
Paradise whydah (*Steganura paradisea*)	3
Shaft-tailed whydah (*Tetrænura regia*)	2
Napoleon weaver (*Pyromelana afra*)	1
Red-billed weaver (*Quelea quelea*)	1
Madagascar weaver (*Foudia madagascariensis*)	1
St. Helena waxbill (*Estrilda astrilda*)	3
Rosy-rumped waxbill (*Estrilda rhodopygia*)	1
Nutmeg finch (*Munia punctulata*)	3
White-headed nun (*Munia maja*)	2
Black-headed nun (*Munia atricapilla*)	13
Chestnut-breasted finch (*Munia castaneithorax*)	4
Java finch (*Munia oryzivora*)	14
White Java finch (*Munia oryzivora*)	1
Masked grassfinch (*Poëphila personata*)	6
Black-faced Gouldian finch (*Poëphila gouldiæ*)	1
Red-faced Gouldian finch (*Poëphila mirabilis*)	1
Diamond finch (*Steganopleura guttata*)	8
Zebra finch (*Tæniopygia castanotis*)	17

PASSERIFORMES—continued

Cutthroat finch (*Amadina fasciata*)	12
Red-headed finch (*Amadina erythrocephala*)	2
Hooded oriole (*Icterus cucullatus*)	2
Yellow-tailed oriole (*Icterus mesomelas*)	1
Purple grackle (*Quiscalus quiscula*)	2
Greenfinch (*Chloris chloris*)	3
European goldfinch (*Carduelis carduelis*)	4
Bramble finch (*Fringilla montifringilla*)	5
Yellowhammer (*Emberiza citrinella*)	3
House finch (*Carpodacus mexicanus frontalis*)	2
San Lucas house finch (*Carpodacus mexicanus ruberrimus*)	2
Canary (*Serinus canarius*)	20
Gray singing finch (*Serinus leucopygius*)	10
Slate-colored junco (*Junco hyemalis*)	1
White-throated sparrow (*Zonotrichia albicollis*)	2
San Diego song sparrow (*Melospiza melodia cooperi*)	3
Saffron finch (*Sicalis flaveola*)	10
Seed eater (*Sporophila gutturalis*)	2
Nonpareil (*Passerina ciris*)	2
Leclancher's nonpareil (*Passerina leclancheri*)	2
Cardinal (*Cardinalis cardinalis*)	1
Red-crested cardinal (*Paroaria cucullata*)	3

REPTILES

Alligator (*Alligator mississipiensis*)	43
Water dragon (*Physignathus lesueurii*)	3
Horned toad (*Phrynosoma cornutum*)	1
Glass snake (*Ophisaurus ventralis*)	1
Gila monster (*Heloderma suspectum*)	6
Gould's monitor (*Varanus gouldii*)	3
Blue-tongued lizard (*Tiliqua scincoides*)	1
Rock python (*Python molurus*)	2
Regal python (*Python reticulatus*)	1
Anaconda (*Eunectes murinus*)	2
Boa constrictor (*Constrictor constrictor*)	2
Black snake (*Coluber constrictor*)	5
Blue racer (*Coluber constrictor flaviventris*)	6
Coachwhip snake (*Coluber flagellum*)	2
Chicken snake (*Elaphe quadrivittata*)	1
Corn snake (*Elaphe guttata*)	2
Pilot blacksnake (*Elaphe obsoleta*)	1
Pine snake (*Pituophis melanoleucus*)	4
Bull snake (*Pituophis sayi*)	4
Western bull snake (*Pituophis catenifer*)	1
Water snake (*Natrix sipedon*)	1
Western water snake (*Natrix sipedon fasciata*)	1
Garter snake (*Thamnophis sirtalis*)	1
Western diamond rattlesnake (*Crotalus atrox*)	4

Snapping turtle (*Chelydra serpentina*)	5
Rossignon's snapping turtle (*Chelydra rossignonii*)	1
Musk turtle (*Kinosternon odoratum*)	1
Mexican musk turtle (*Kinosternon sonoriense*)	1
South American musk turtle (*Kinosternon scorpioides*)	5
Pennsylvania musk turtle (*Kinosternon subrubrum*)	2
Wood turtle (*Clemmys insculpta*)	1
South American terrapin (*Nicoria punctularia*)	1
Painted turtle (*Chrysemys picta*)	1
Cooter (*Pseudemys scripta*)	2
Central American cooter (*Pseudemys ornata*)	2
Gopher tortoise (*Gopherus polyphemus*)	1
Duncan Island tortoise (*Testudo ephippium*)	1
Indefatigable Island tortoise (*Testudo porteri*)	1
Albemarle Island tortoise (*Testudo vicina*)	2
South American tortoise (*Testudo denticulata*)	2
Long-necked turtle (*Chelodina longicollis*)	1

STATEMENT OF THE COLLECTION

Accessions during the year

	Mammals	Birds	Reptiles	Total
Presented	45	124	52	221
Born and hatched in National Zoological Park	42	27		69
Received in exchange	12	60	4	76
Purchased	9	81	8	98
Transferred from other Government departments	7	11		18
Captured		2		2
Deposited	3	4		7
Total	118	309	64	491

SUMMARY

Animals on hand July 1, 1923	1,768
Accessions during the year	491
Total animals handled	2,259
Deduct loss (by exchange, death, and return of animals on deposit)	614
Animals on hand June 30, 1924	1,645

Class	Species	Individuals
Mammals	177	458
Birds	276	1,059
Reptiles	41	128
Total June 30, 1924	494	1,645

VISITORS

Attendance records exceeded the previous year (1923) by 49,452 and were 42,043 over the record year for the park (1921). The total number of visitors, as determined by count and estimate, was 2,442,880. This makes the fifth year in succession that the attendance has exceeded two millions. The greatest attendance in any one month was 352,425 in September, 1923.

The attendance by months was as follows:

1923		1924	
July	269,400	January	73,440
August	279,550	February	93,263
September	352,425	March	211,250
October	215,975	April	313,150
November	114,210	May	209,367
December	111,000	June	199,850

Schools, classes, and other similar organizations visiting the park during the year numbered 160, with a total of 15,100 individuals.

It is interesting to note the increase in the number of visitors to the park in the past 12 years. Following are the attendance records from 1913 to 1924:

1913	633, 526	1919	1, 964, 715
1914	733, 277	1920	2, 229, 605
1915	794, 530	1921	2, 400, 837
1916	1, 157, 110	1922	2, 164, 254
1917	1, 106, 800	1923	2, 393, 428
1918	1, 593, 227	1924	2, 442, 880

IMPROVEMENTS

Work on the new paddocks for hoofed animals near the Connecticut Avenue entrance, described fully in the last report, was finished early in the year, and the 11 yards thus provided were all occupied by animals in the fall. The superior arrangement of these paddocks for the care and exhibition of the animals has been very favorably commented upon by officials from other zoological gardens, and the pleasing sight of herds of animals in such large inclosures is greatly admired by visitors.

In late winter the birds were all removed from the North American waterfowl lake and early in the spring the lake was thoroughly cleaned of silt. The work was completed so that the waterfowl were returned before the season for nesting. The sewer from the office and stables was extended to connect with the Rock Creek intercepting sewer. A new sidewalk on the east side of the road opposite the restaurant building was completed, and roads, walks, and bridle paths throughout the park were repaired. Two old boilers in the central heating plant were replaced with new boilers of improved pattern, thus considerably increasing the heating capacity of the plant.

The usual repairs to roofs, gutters and downspouts, fences, and cages were made and much of the ironwork was painted. The old metal awning frames over the walk around the bear cages were removed, since these unsightly frames were no longer needed, the trees now providing ample shade. Work was begun on the warehouse for new or surplus animals, approved in the last plan of operations. This long-needed structure will be completed in the present year.

The most important improvement of the year has been the complete reconstruction of the central refreshment building. The old restaurant was found to be in such bad condition that very little of the material in it could be used, and in order to provide the new structure with suitable foundations it was almost entirely wrecked. The new restaurant is built chiefly of chestnut timbers salvaged

from the dead trees in the reservation, and adds greatly to the appearance of the park. It was leased to a competent restaurant man, who opened it to the public in April.

IMPORTANT NEEDS

Exhibition building for birds.—The outstanding need of the park is a new building for exhibition of birds. As pointed out in previous reports, the old bird house was built as a temporary structure many years ago, and is now not only in bad condition and virtually beyond repair but is so small that only a part of the valuable collection of birds can be exhibited at one time. The public space is, furthermore, entirely too restricted for present-day crowds of visitors. The collection of birds is growing in importance and value year by year, as rare and unusual specimens from all parts of the world are presented to the Government zoological gardens. Public interest in the bird collection is very great, as attested by the throngs of visitors that fill the old bird house, and it is greatly to be hoped that a new building may soon be provided for the proper care and exhibition of the birds and for the accommodation of the constantly increasing number of visitors who wish to see them to advantage.

Funds for purchase of animals.—Although the National Zoological Park receives numerous animals each year as gifts or in exchange for surplus stock reared in the park, sufficient funds have never been available for the purchase of rare and unusual species offered for sale from time to time. A representative or well-balanced collection of the living animals of the world can be built up and maintained only by the purchase of certain types of animals not otherwise obtainable, and opportunities to secure these desiderata must be taken up promptly if the animals are to be obtained. Animals greatly needed to fill definite gaps in the collection are offered for sale from time to time, but the park is most often unable to purchase them for lack of funds. In addition to increased appropriations to cover cost and transportation of animals, it is suggested that a fund, to be deposited with the Smithsonian Institution and held for the purchase of animals for the National Zoological Park, be inaugurated. This fund might be increased by gift or bequest, and could be regularly maintained by an act of Congress authorizing deposit in it of certain miscellaneous revenues of the park now turned into the general fund of the Treasury, these including rent of refreshment stands, restaurant, and other similar concessions.

Respectfully submitted.

N. Hollister, *Superintendent.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 7

REPORT ON THE ASTROPHYSICAL OBSERVATORY

SIR: The Astrophysical Observatory was conducted under the following passage of the independent offices appropriation act approved February 13, 1923:

Astrophysical Observatory: For maintenance of the Astrophysical Observatory, under the direction of the Smithsonian Institution, including assistants, purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, repairs and alterations of buildings, and miscellaneous expenses, $15,500.

The observatory occupies a number of frame structures within an inclosure of about 16,000 square feet south of the Smithsonian administration building at Washington, and also a cement observing station and frame cottage for observers on a plot of 10,000 square feet leased from the Carnegie Solar Observatory on Mount Wilson, Calif.

A new solar observing station on Mount Harqua Hala, Ariz., was erected in July, 1920, at the expense of funds donated for the purpose by Mr. John A. Roebling, of Bernardsville, N. J., and this station has been occupied as a solar radiation observing station by the Astrophysical Observatory since October, 1920.

The present value of the buildings and equipment for the Astrophysical Observatory owned by the Government is estimated at $50,000. This estimate contemplates the cost required to replace the outfit for the purposes of the investigation.

WORK OF THE YEAR

There have been several features of particular interest, including the installation of daily telegraphic reports from the Arizona and Chile solar-radiation stations, certain experimental forecasts based on these reports, and the measurement of the energy distribution in the spectra of 10 of the brighter stars.

Work at Washington.—As in previous years, the variation of the sun has been the main concern. The generosity of Mr. John A. Roebling enabled arrangements to be made for daily telegrams from our two solar radiation stations. This service was begun September 13, 1923. The results obtained in Chile are cabled in code, so that the weighted mean solar-constant value, the date and hour of observa-

tion, and its grade are all included in two words. Messages arrive at Washington from both stations within 24 hours of the actual measurements, and generally represent mean results of five independent determinations at each station. Arrangements have been made (also owing to Mr. Roebling's interest and generosity) to test the value of the solar measurements for forecasting according to the methods of Mr. H. H. Clayton. For this purpose Mr. Clayton has had a small office[1] and one assistant near his home in Canton, Mass., where he receives before noon daily from the Smithsonian Institution the weighted mean of the solar-constant values observed in Arizona and Chile on the preceding day. He makes his forecasts for 3, 4, 5, and 27 days in advance, and mails them to the Institution on the same afternoon. Thus we receive the forecasts sufficiently long before their maturity to make a very real and searching test of their validity.

These forecasts for definite days relate to the mean temperature of New York City, and are later on compared with the observed temperatures and analyzed by several purely mathematical methods quite independently of any bias of the computer. The official weather services of the various countries do not, of course, make predictions parallel to these, except in Argentina, where such forecasts are made by similar methods to Clayton's. Hence it is impossible to know at present how much gain, if any, Mr. Clayton's solar forecasts show over the present official methods. That they do show some prevision of the event, even to five days after the solar observations, is certain.

Hitherto, however, the 27-day detailed forecasts have shown no correlation with the New York temperatures. This is not at all surprising. Indeed, all such forecasts have to contend against great odds. For we recall that the march of temperature often goes quickly from crest to trough, so that even if a true forecast could be made, and it should be no more than 12 or 24 hours off in point of time, there would be large divergences between the prediction and the event. With the unyielding mathematical methods of verification this would greatly diminish the correlation found.

A fairer test for very long-range forecasts is found in general statements as to the expected departure from mean normal temperatures for coming months. These Mr. Clayton has furnished from 15 to 30 days before the beginning of each month from December, 1923, to the present time. He also furnishes similar predictions about the approaching weeks furnished three days before the beginning of the week in question. With few exceptions, these broader prognostications have been fairly verified.

[1] Thanks are due to the Canton Historical Society for use of these quarters.

On the whole, therefore, although the results are as yet far from being entirely satisfying, these experimental forecasts of Mr. Clayton's are promising enough to warrant further trial. New methods are continually being devised and tried in making them. Mr. Roebling has generously arranged to continue them until June 30, 1925. As the work is purely experimental no detailed publication of it will be made at present.

Naturally, if the forecasts made by Mr. Clayton really represent solar changes, he can not succeed unless good solar measurements are supplied. As soon as we began to receive daily telegrams from both stations occasional fairly wide disagreements of individual days commanded attention. We felt it necessary, in studying the causes of such disagreements, to revise again entirely the systems of little corrections to solar-constant values which have to be made to allow for the haziness and humidity of our atmosphere. This revision could be made with more advantage because much additional data had meanwhile accumulated.

Mr. Fowle and Mrs. Bond have worked over this matter during practically their entire time, which, however, owing to furlough, was only about three months in Mrs. Bond's case. A new method of determining these corrections has been devised by the director and Mr. Fowle, which eliminates satisfactorily the influence of the solar changes which have occurred. Hitherto this matter of solar change superposed upon the small terrestrial sources of error which we desire to eliminate has been very embarrassing. Of course, if one could wait many years before proceeding to evaluate the terrestrial effects, the solar changes, being independent or but loosely connected with local terrestrial ones, would be eliminated in the mean of a mass of observations. We can, indeed, after several years more of observing, finally proceed in this way. But wishing to make immediate use of our results a new method of procedure has fortunately occurred to us which permits us to avoid the interference of solar changes altogether. The details will be published soon.

As both to us and to the Chief of the Weather Bureau it seemed unwise to publish preliminary values of the solar constant which later on would have to be corrected, we have discontinued the frequent publications of them in the Monthly Weather Review which we have been accustomed to make for several years past. After we come to a fully satisfactory basis of systematic atmospheric corrections, these publications may be resumed.

Of the two solar-radiation stations, Montezuma, Chile, has proved far more suitable to the purpose than Harqua Hala, Ariz. It seems probable that a place somewhat farther west and decidedly higher would be preferable to Mount Harqua Hala. Violent storms occur there in various months of the year, and the summer months in par-

ticular have proved very unsatisfactory. If financial means were available it would be highly desirable to remove the station to another site, and, indeed, a better one is already selected which would present many advantages. The cost of removal would be about $7,000.

The systematic revision of results in the hands of Mr. Fowle and Mrs. Bond has led to much improvement, as shown by the close accord of daily solar-constant values at the two stations. For the period September, 1922, to March, 1924, the average daily difference is less than 0.5 per cent. In the month of October, 1923, when the weather was fine at both stations almost every day, it ran as low as 0.2 per cent.

The solar-constant values have continued almost without exception below normal. From March, 1922, until June, 1924, the mean result for every single month was below the normal value, which is 1.938 calories per square centimeter per minute. This long-continued defect of solar radiation may well have produced interesting climatic effects. It is interesting to report in this connection a letter from M. Antoniadi, of France, stating that the polar cap of Mars is larger than it has been under parallel conditions for 70 years, and asking if the solar-radiation measurements showed anything unusual. Naturally decreased solar radiation would tend to produce that effect.

A letter from the eminent meteorologist, Doctor Bjerknes, of Norway, to Doctor Hale, of the Mount Wilson Observatory, has been referred to us, and with permission of the author is here copied in part as an indication of expert appreciation of our work:

> I have been greatly interested in the establishment of a complete "circumpolar" weather service, as this only will give the full view of the changing states of the atmosphere. This circumpolar service is now beginning to become a reality. The charts may soon more or less cover the entire northern hemisphere.
>
> But then another idea arises by itself, namely, to bring these more and more complete pictures of the varying states of our atmosphere into connection with their ultimate cause, the solar activity. * * *
>
> I am aware that the solar constant is determined every day at Mount Wilson Solar Observatory, and at the Calama Observatory of the Smithsonian Institution. * * * I think it would now be of high importance to every day have the most recent value of the solar constant incorporated in the daily meteorological issue.
>
> If this should be practicable, the value of the data which are every day at the disposal of the meteorologist would increase enormously. It is, of course, dangerous to prophesy. But a new era may perhaps begin for meteorology from the moment when the meteorologist has at his disposal every day complete data both for the sun's activity and for the state of the atmosphere over an entire hemisphere of the earth.

Work at the two solar-radiation stations.—The results just discussed are, of course, the fruit of the zealous work of our observers in

Arizona and Chile. Mount Harqua Hala continues under the direction of Mr. A. F. Moore, who was assisted until March 1, 1924, by Mr. P. E. Greeley. After Mr. Greeley's resignation, Mr. A. H. Worthing assisted from May 20 to June 30, but then resigned. At Montezuma, Chile, the station continued in charge of Mr. L. B. Aldrich, assisted by Mr. F. A. Greeley.

Many comforts and observing improvements have been added at both stations at small expense owing to the ingenuity and hard manual labor of the observers. At both stations all possible days for solar-constant work have been utilized, and with very high accuracy of observation. About 75 per cent of all days were observed in Arizona and above 80 per cent in Chile. The months of July, August, and September, however, were very unfavorable at Harqua Hala, because of unusual cloudiness which prevailed all over that section of the United States. This abnormal state of the sky was indeed made specially prominent by the almost complete failure of all the California observations of the total solar eclipse of September 10, 1923. Many observations of these months must be rejected on account of unfavorable sky.

Mr. W. H. Hoover assisted Mr. Moore for a few weeks in May, 1923. While Mr. and Mrs. Moore were away in Australia setting up near Sydney a solar-radiation outfit ordered by Rev. E. F. Pigot, of Riverview College, for a committee of interested Australians, Mr. and Mrs. Hoover relieved them at Harqua Hala from July until September. Mr. Hoover was thus prepared by actual field experience to be director of the Argentine Government's new solar-radiation station at La Quiaca.

The outfit for this station was prepared at the Smithsonian Institution after designs of the writer, and the finer parts, such as those of the bolometer and galvanometer, were constructed by Mr. Hoover. Shipment was made in January, 1924, and the station at La Quiaca made ready for solar observing in June, 1924. Thus the Argentine Government is the first agency outside the Smithsonian Institution to undertake regular determinations of the variation of the sun. Their official weather service still receives daily telegraphic reports from our station at Montezuma, Chile, and it will supplement these by its own solar-radiation measurements at La Quiaca.

Field work at Mount Wilson.—The director and Mrs. Abbot occupied this station from July to October, 1923. Three objects were in view—First, to set up apparatus and begin observations on the variations of atmospheric ozone after the ingenious spectroscopic method of Fabry and Buisson. M. Fabry was so kind as to supervise the ordering in Paris of all the special quartz and fluorite optical parts needed. Owing to the detached service of the Smithsonian instru-

ment maker, Mr. Kramer, who was engaged in making the Australian and Argentine solar radiation outfits, no work had been done toward mounting the optical parts for ozone studies or, indeed, toward preparing for other experiments of the expedition. So it happened that the director spent several weeks on Mount Wilson at instrument making and was not quite ready to begin the ozone observations in 1923.

The second object was to test new improvements on the solar cooker. By the lively interest of Director Stratton, the Bureau of Standards had constructed by their skillful glass blower, Mr. Sperling, a long, pyrex-glass, double-walled vacuum tube to inclose the heater tube of the Mount Wilson solar cooker. As stated in Volume IV of the Annals of the Astrophysical Observatory, nearly nine-tenths of the loss of heat had hitherto occurred from the heater tube within the great mirror. It was to check this loss that the new device was planned.

Unfortunately, the aluminum of the mirror was found much deteriorated and could not be fully restored by polishing. Hence the mirror was very inefficient in 1923. Nevertheless, the vacuum tube showed its efficiency by the fact of the heating of the oven to 175° C., or fully 25° C. above the usual maximum temperatures of 1920. But new troubles arose. The oil circulation became leaky at the new high temperature, spontaneous combustion of the cotton heat insulation occurred, and the experiments had to be stopped after long-continued vain attempts to close the leaks by soldering. Also the vacuum tube, which was really made too long for safety, soon broke under the unequal heating strains. After this breakage occurred the maximum temperatures attained were but 120° C., showing that over 50° C. of advantage came from the employment of the vacuum device. The experiments seemed so promising that a continuation of them was arranged for 1924, and new and improved instrumental constructions were prepared by Mr. Kramer during the winter months

The third piece of work attempted was with the 100-inch telescope on the energy spectrum of the brighter stars. Messrs. Abbot and Aldrich had, indeed, done this with moderate success in 1922, employing the vacuum bolometer and galvanometer. But great trouble had been found in the use of those instruments at extreme sensibility. Fortunately, the late Dr. E. F. Nichols had offered to have prepared a radiometer of improved design for the work. This instrument, constructed by Dr. J. D. Tear, proved equally as sensitive as the bolometer used in 1922, and practically as easy to use as a meter stick.

With it and with a new optical arrangement designed by the writer, and largely constructed by him, very interesting results were obtained. The spectra of 10 stars, including the sun, as cast by a 60° flint-glass prism, were measured successfully. As the sun's energy spectrum is well known, it was possible to eliminate by comparison with it all of the chief instrumental and atmospheric losses. Thus the results appear as stellar energy curves outside our atmosphere, expressed on the normal or wave-length scale. As the deflections observed were fairly large, no less than 50 millimeters at maximum in the spectrum of Betelgeuse, for example, the curves are of very fair accuracy over most of their extent. It was possible to improve them in the shorter wave-length region where they were inaccurate by employing visual and photographic results of German observers. Thus the whole of the intense part of the spectrum of the yellow and red stars and a large part of that of the white and blue ones were well delineated. From these results good estimates could be made of the star temperatures on the "black-body" basis. Furthermore, estimates of the diameters necessary in "black bodies" to produce at those temperatures the observed amounts of energy were made. It is gratifying to find these results on stellar diameters as accordant as could be expected with those of Pease made by means of Michelson's method of the interferometer. A summary follows:

Stellar temperatures, radiation, and diameters

Star	Absolute temperature C.	N [1] Unit = 10^{-11}	Parallax	Diameter ⊙=1 [2]		
				Radiometer	Interferometer	Russell
	Degrees		*″*			
Sun	6,000					
β Orionis	16,000	3.20	0.007	20		2.8
α Lyrae	14,000	6.10	.130	2		3.
α Canis Majoris	11,000	6.60	.370	1.2	2	
α Canis Minoris	8,000	1.24	.315	1.1		1.6
x Aurigae	5,800	2.20	.071	13		9.
α Tauri	3,000	2.54	.053	70	39	
β Pegasi	2,850	1.11	.026	94	82	
α Orionis	2,600	7.90	.017	510	280	
α Herculis	2,500	3.60	.007 .013	900 480		230.

[1] N=ratio of stellar to solar radiation outside earth's atmosphere.
[2] To express in kilometers, multiply by 1.42×10^6. To express in miles, multiply by 0.865×10^6.

SUMMARY

The year has been notable for the establishment of daily telegraphic solar-constant intelligence from Montezuma, Chile, and Harqua Hala, Ariz., through the interest and generosity of Mr. John A. Roebling. Also, due to the same support, experimental temperature forecasts for New York City, based on these daily reports of

solar changes, have been regularly submitted by Mr. H. H. Clayton for certain periods of time in advance. Revision of the solar radiation results of the two stations shows average daily accord to less than 0.5 per cent in their solar-constant determinations. Observations have been received from one or both solar-radiation stations on about 90 per cent of all days. Further experiments with the solar cooker have resulted in some advancement and have pointed the way to further progress. Apparatus has been made ready for determinations of atmospheric ozone after the method of Fabry and Buisson. Highly interesting results on stellar energy spectrum distribution and on star diameters have been obtained with a Nichols radiometer in cooperation with the Mount Wilson Observatory of the Carnegie Institution.

Respectfully submitted.

C. G. Abbot, *Director.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 8

REPORT ON THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

SIR: I have the honor to submit the following report on the operations of the United States Regional Bureau of the International Catalogue of Scientific Literature for the fiscal year ending June 30, 1924.

As has been stated in several previous annual reports, political and financial conditions in Europe, caused by the late war, forced a suspension of the printing and publishing of the International Catalogue after the fourteenth annual issue had been completed in July, 1921. A total of 240 volumes had been published up to the time that printing was suspended. This series of publications constitutes a classified index catalogue of the scientific literature of the world for 14 years, from 1901 to 1914, inclusive, and furnishes the only example of such work ever published. In spite of numerous attempts to resume publication it has been found impossible to do so in the face of the continued unsettled condition of international monetary standards. The continued high price of materials and labor entering into publishing expenses brings the cost of the 10,000 pages of each annual issue of the catalogue up to impossible figures when expressed in terms of the depreciated currency of many of the cooperating countries.

In 1922, finding that immediate resumption of publication was impossible, an international convention was held in Brussels to consider means whereby the organization could be held intact. A resolution to this end was suggested by this regional bureau and was unanimously agreed to. The resolution was:

> That the convention is of opinion that the international organization should be kept in being through mutual agreement to continue as far as possible the work of the regional bureaus until such time as it may be economically possible to resume publication.

The other countries represented at this convention, as well as the United States, have since that time lived up to the spirit of this resolution.

The present aim of this bureau is to collect and record the data necessary to index the current scientific publications of the United States without attempting to classify the subjects of the papers themselves, for before publication is resumed it will be necessary to completely revise the classification schedules heretofore used in order to keep abreast with ever advancing scientific discoveries and

the consequently changing requirements of investigators and students.

The need of a definite, concrete, and internationally satisfactory plan of operation to govern any organization undertaking to index and classify current scientific literature is now more evident than it was 24 years ago when the International Catalogue was founded, for since the publication of the catalogue by this organization was suspended many plans have been suggested but none have so far been found satisfactory or practical. Schemes which take into consideration only local or special needs are found useless when world-wide needs are considered. And when such schemes are compared with the far-reaching, time-tried, and officially recognized organization of the International Catalogue of Scientific Literature, whose scope embraces all scientific subjects and whose field is world-wide, their inadequacy is at once apparent.

In aiming to meet the various needs of scientific specialists and students several forms of service are required:

1. Immediate notices which may be furnished by means of cards or assembled reference data to meet the requirements of specialists in restricted fields.

2. Monthly or quarterly classified records furnishing not only complete index data but also, to meet the needs of general students as well as specialists, brief abstracts of the subject contents of each paper noted.

3. Yearly catalogues or yearbooks, each covering a recognized subdivision of science, collectively furnishing a permanent, assembled, classified record of all scientific activities. Such collective records are the only ones suited to meet the needs and requirements of librarians as well as future investigators.

As in the preparation of each of these aids to scientific investigation the same materials are required and the same methods of indexing and classifying are employed, it is evident that consolidation, or at least close cooperation, should exist between all organizations undertaking such work.

Many abstracting agencies now exist and attempts are being made to establish more, but taken collectively they fail to cover all branches of science and are too dissimilar in their methods and form of publication to take the place of a concise, classified, permanent record of scientific publications so urgently needed by specialists and librarians alike. It was chiefly to meet this need that the International Catalogue was originally founded.

Respectfully submitted.

LEONARD C. GUNNELL,
Assistant in Charge.

DR. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 9

REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the library of the Smithsonian Institution and of the libraries of the bureaus under its administration for the fiscal year ended June 30, 1924.

The use of the library by members of the Smithsonian staff has been stimulated by the publication each fortnight in Smithsonian Local Notes of principal additions to the collections and by the daily circulation among heads of scientific departments and divisions of a typewritten list of original articles appearing in periodicals received for the main library.

While the libraries administered under the Smithsonian Institution are used principally for reference in connection with advanced scientific and technological research and special administrative problems, their facilities are open to all. Every book is available to the public, through consultation, by borrowing through an accredited library, or by means of photographic reproduction at the correspondent's expense.

SMITHSONIAN MAIN LIBRARY

The number of publications received for the main library was 8,678, consisting of 4,044 volumes, 2,126 parts, 2,332 pamphlets, and 176 charts. The total number of accessions has reached 544,980, representing 901,985 publications.

Theses and academic publications were received from abroad from universities located at the following places: Algiers, Berlin, Bern, Copenhagen, Dijon, Dorpat, Freiburg, Giessen, Graz, Halle, Kiel, Königsberg, Liège, London, Lund, Manchester, Marburg, Montpellier, Paris, Prague, Rennes, Strasbourg, Tokyo, Utrecht, Vienna, Warsaw, Wilno, and Zürich.

Of a total of 3,352 missing parts of incomplete sets requested in exchange, 1,786 were secured, a percentage of 53.2 as compared with 43.2 last year.

SMITHSONIAN OFFICE LIBRARY

The loans from the office library were 2,749. The number of volumes catalogued was 5,348. The number of new titles added to the author catalogue was 1,125.

The gift of Dr. F. W. Clarke of 170 pamphlets, in continuation of his collection of papers on the atomic weights, brought the total number of publications accessioned up to 477.

There were 51 additions to the aeronautical collection. The growth of this collection during the past decade has been due almost entirely to the personal efforts of Mr. Paul Brockett, who has secured for it many rare and valuable works, the acquisition of which would otherwise have entailed great expense.

The cataloguing of the European Historical Series of the Watts de Peyster collection is approaching completion.

UNITED STATES NATIONAL MUSEUM

The library of the National Museum now contains 63,691 volumes and 101,057 pamphlets, making a total of 164,748 publications. Of these 1,521 volumes and 2,667 pamphlets represent the increase of the year; 14,528 parts of periodicals were entered. Owing to lack of funds, only 163 books were bound.

The number of loans reached a total of 10,577. Many more volumes were consulted without being taken out. There were borrowed 1,929 books from the Library of Congress and 130 from other libraries.

When it is realized that 6,139 of the library's loans were made to the sectional libraries, the importance of the latter will become readily apparent. The sectional libraries maintained are as follows:

Administration.
American archeology.
Anthropology.
Birds.
Botany.
Echinoderms.
Editor's office.
Ethnology.
Fishes.
Foods.
Geology.
Graphic arts.
History.
Insects.
Invertebrate paleontology.
Mammals.
Marine invertebrates.
Mechanical technology.
Medicine.
Minerals.
Mineral technology.
Mollusks..
Old World archeology.
Paleobotany.
Photography.
Physical anthropology.
Property clerk's office.
Reptiles and batrachians.
Superintendent's office.
Taxidermy.
Textiles.
Vertebrate paleontology.
War library.
Wood technology.

The sectional libraries are under the immediate custody of members of the administrative and scientific staffs, to whom the Museum is also indebted for many valuable gifts to the library and timely suggestions for the increase of its collections in the fields listed above. Among the donors for the present year should be mentioned Messrs. Paul Bartsch, R. S. Bassler, J. E. Benedict, A. G.

Boving, Austin H. Clark, F. W. Clarke, W. H. Dall, C. T. Greene, O. P. Hay, W. H. Holmes, Aleš Hrdlička, E. W. Keyser, W. R. Maxon, G. S. Miller, A. J. Olmsted, C. W. Richmond, S. A. Rohwer, B. H. Swales, and Charles D. Walcott. The gifts of Doctor Dall to the sectional library of mollusks numbered 167 titles. Through the efforts of Doctor Bassler, the Museum has been fortunate in securing the library of the late Edgar E. Teller, paleontologist, of Buffalo, N. Y. The books were received shortly before the close of the fiscal year.

The number of cards added to the subject catalogue was 2,810.

OTHER BRANCH LIBRARIES

The branch libraries at the Astrophysical Observatory, the National Zoological Park, the National Gallery of Art, and the Freer Gallery of Art received a number of accessions during the year. The activities of the library of the Bureau of American Ethnology are covered in the report of the chief of that bureau.

SUMMARY OF RECEIPTS AND ACCESSIONS

The number of pieces of mail received during the year was 28,783, of which 7,321 publications were Government documents, and were sent to the Library of Congress, in accordance with the established practice. Additions to the library, as shown by the accession records, are given below.

Library	Volumes	Other publications	Total
Astrophysical Observatory	89	60	149
Freer Gallery of Art	380		380
National Gallery of Art	132	226	358
National Zoological Park	16	3	19
Smithsonian deposit	4,044	4,634	8,678
United States National Museum	1,521	2,667	4,188
Smithsonian office	277	200	477
Total	6,459	7,790	14,249

Respectfully submitted.

N. P. Scudder,
Acting Assistant Librarian.

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

APPENDIX 10

REPORT ON PUBLICATIONS.

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches during the year ending June 30, 1924:

The Institution proper published during the year 13 papers in the series of Miscellaneous Collections, and 1 special publication. The Bureau of American Ethnology published 3 bulletins and a list of the publications of the bureau. The United States National Museum published 1 annual report, 1 volume of proceedings, 3 complete bulletins, 4 parts of bulletins, 4 parts of volumes in the series Contributions from the United States National Herbarium, and 39 separates from the proceedings.

Of these publications there were distributed during the year 142,385 copies, which includes 407 volumes and separates of the Smithsonian Contributions to Knowledge, 25,937 volumes and separates of the Smithsonian Miscellaneous Collections, 19,085 volumes and separates of the Smithsonian annual reports, 3,743 Smithsonian special publications, 78.734 volumes and separates of the various series of the National Museum publications, 13,974 publications of the Bureau of American Ethnology, 78 publications of the National Gallery of Art, 65 volumes of the Annals of the Astrophysical Observatory, 35 reports on the Harriman Alaska Expedition, 1.275 reports of the American Historical Association, and 52 publications presented to but not issued directly by the Smithsonian Institution or its branches.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

Of the Smithsonian Miscellaneous Collections, volume 67, 1 paper was issued; volume 71, 1 paper; volume 73, 1 paper; volume 75, 1 paper; volume 76, 9 papers; in all, 13 papers, as follows:

VOLUME 67

No. 9. Cambrian Geology and Paleontology. IV. No. 9. Cambrian and Ozarkian Brachiopoda, Ozarkian Cephalopoda and Notostraca. By Charles D. Walcott. June 3, 1924. Pp. 477–554; pls. 106–126. (Publ. 2753.)

VOLUME 71

No. 1. Smithsonian Physical Tables. Second reprint of seventh revised edition. November 28, 1923. 458 pp. (Publ. 2539.)

VOLUME 73

No. 2. Opinions Rendered by the International Commission on Zoological Nomenclature. Opinions 78 to 81. February 9, 1924. 32 pp. (Publ. 2747.)

VOLUME 75

No. 1. Cambrian Geology and Paleontology. V. No. 1. Geological Formations of Beaverfoot-Brisco-Stanford Range, British Columbia, Canada. By Charles D. Walcott. June 28, 1924. Pp. 1–51, pls. 1–8, text figs. 1–11. (Publ. 2756.)

VOLUME 76

No. 2. History of Electric Light. By Henry Schroeder. August 15, 1923. 95 pp., 97 illus. (Publ. 2717.)

No. 3. On the Fossil Crinoid Family Catillocrinidae. By Frank Springer. August 3, 1923. 41 pp., 5 pls. (Publ. 2718.)

No. 4. Report on Cooperative Educational and Research Work Carried on by the Smithsonian Institution and Its Branches. July 28, 1923. 30 pp. (Publ. 2719.)

No. 5. The Telescoping of the Cetacean Skull. By Gerrit S. Miller, jr. August 31, 1923. 70 pp., 8 pls. (Publ. 2720.)

No. 6. Descriptions of New East Indian Birds of the Families Turdidae, Sylviidae, Pycnonotidae, and Muscicapidae. By Harry C. Oberholser. July 16, 1923. 9 pp. (Publ. 2721.)

No. 7. Description of an Apparently New Toothed Cetacean from South Carolina. By Remington Kellogg. July 25, 1923. 7 pp., 2 pls. (Publ. 2723.)

No. 8. Additional Designs on Prehistoric Pottery. By J. Walter Fewkes, Chief, Bureau of American Ethnology. January 22, 1924. 46 pp., 101 text figs. (Publ. 2748.)

No. 9. The Brightness of Lunar Eclipses, 1860–1922. By Willard J. Fisher. February 18, 1924. 61 pp. (Publ. 2751.)

No. 10. Explorations and Field Work of the Smithsonian Institution in 1923. March 31, 1924. 128 pp., 123 text figs. (Publ. 2752.)

SMITHSONIAN ANNUAL REPORTS

Report for 1922.—The Annual Report of the Board of Regents for 1922 was still in press at the close of the fiscal year. The general appendix to this report contains the following articles:

Who will promote science? by C. G. Abbot.
Recent discoveries and theories relating to the structure of matter, by Karl Taylor Compton.
The architecture of atoms and a universe built of atoms, by C. G. Abbot.
Aeronautic research, by Joseph S. Ames.
Photosynthesis and the possible use of solar energy, by H. A. Spoehr.
Fogs and clouds, by W. J. Humphreys.
Some aspects of the use of the annual rings of trees in climatic study, by Prof. A. E. Douglass.
The age of the earth, by T. C. Chamberlin and others.
How deep is the ocean? by C. G. Abbot.
Two decades of genetic progress, by E. M. East.
Observations on a Montana beaver canal, by S. Stillman Berry.

The Republic of Salvador, by Paul C. Standley.
The tent caterpillar, by R. E. Snodgrass.
The life history and habits of the solitary wasp, *Philanthus gibbosus*, by Edward G. Reinhard.
The use of idols in Hopi worship, by J. Walter Fewkes.
Two Chaco Canyon pit houses, by Neil M. Judd.
Collections of Old World archeology in the United States National Museum, by I. M. Casanowicz.
The "Shake Religion" of Puget Sound, by T. T. Waterman.
Excavations at Askalon, by Prof. J. Garstang.
National efforts at home making, by F. H. Newell.
Ideals of the telephone service, by John J. Carty.

Report for 1923.—The report of the executive committee and proceedings of the Board of Regents of the Institution, and the report of the secretary, both forming parts of the annual report of the Board of Regents to Congress, were issued in pamphlet form in December, 1923.

Report of the executive committee and proceedings of the Board of Regents of the Smithsonian Institution for the year ending June 30, 1923. 13 pp. (Publ. 2750.)
Report of the Secretary of the Smithsonian Institution for year ending June 30, 1923. 125 pp. (Publ. 2749.)

The general appendix to this report, which was in press at the close of the year, contains the following papers:

The constitution and evolution of the stars, by Henry Norris Russell.
The sun and sunspots, 1820–1920, by E. Walter Maunder.
Joining the electric wave and heat wave spectra, by E. F. Nichols and J. D. Tear.
The possibilities of instrumental development, by George E. Hale.
The borderland of astronomy and geology, by Prof. A. S. Eddington.
Atmospheric nitrogen fixation, by Eric A. Lof.
The place of proteins in the diet in the light of the newer knowledge of nutrition, by H. H. Mitchell.
The story of the production and uses of ductile tantalum, by Clarence W. Balke.
The composition of the earth's interior, by L. H. Adams and N. L. Williamson.
Diamond-bearing peridotite in Pike County, Ark., by H. D. Miser and C. S. Ross.
Recent progress and trends in vertebrate paleontology, by W. D. Matthew.
Animals in the National Zoological Park, by N. Hollister.
The burrowing rodents of California as agents in soil formation, by Joseph Grinnell.
The natural history of China, by A. de C. Sowerby.
Life in the ocean, by Austin H. Clark.
A study of the flight of sea gulls, by R. C. Miller.
Insect musicians and their instruments, by R. E. Snodgrass.
The gardens of ancient Mexico, by Mrs. Zelia Nuttall.
A new national monument (Hovenweep), by J. Walter Fewkes.
The genesis of the American Indian, by A. Hrdlička.
Ruined cities of Palestine, east and west of the Jordan, by Arthur W. Sutton.

The anthropological work of Prince Albert 1st of Monaco and recent progress in human paleontology in France, by Marcellin Boule.
The utilization of volcanic steam in Italy.
Proposed tidal hydroelectric power development of Petitcodiac and Memramcook Rivers, by W. Rupert Turnbull.
Sir James Dewar, by Sir James Crichton-Browne.
J. C. Kapteyn, by A. Van Maanen.
Julius Von Hann, by C. G. S.

SPECIAL PUBLICATION

The following special publication was issued during the year:

Classified List of Smithsonian Publications Available for Distribution, March 1, 1924. 30 pp. (Publ. 2755.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The publications of the National Museum are: (*a*) The annual report, (*b*) the Proceedings of the United States National Museum, and (*c*) the Bulletin of the United States National Museum, which includes the contributions from the United States National Herbarium. The editorship of these publications is vested in Dr. Marcus Benjamin.

During the year ending June 30, 1924, the Museum published 1 annual report, 1 volume of proceedings, 3 complete bulletins, 4 parts of bulletins, 4 parts of volumes in the series Contributions from the United States National Herbarium, and 39 separates from the proceedings.

The issues of the bulletins were as follows:

Bulletin 99, East African Mammals in the United States National Museum, Part III. Primates, Artiodactyla, Perissodactyla, Proboscidea, and Hyracoidea. By N. Hollister.
Bulletin 100, Contributions to the Biology of the Philippine Archipelago and Adjacent Regions. Volume 1, part 10. The Polyclad Turbellarians from the Philippine Islands. By Tokio Kaburaki.
Bulletin 104, The Foraminifera of the Atlantic Ocean. Part 4. Lagenidae. By Joseph Augustine Cushman.
Bulletin 104, The Foraminifera of the Atlantic Ocean. Part 5. Chilostomellidae and Globigerinidae. By Joseph Augustine Cushman.
Bulletin 125, North American Later Tertiary and Quaternary Bryozoa. By Ferdinand Canu and Ray S. Bassler.
Bulletin 127, Catalogue of the Watercraft Collection in the United States National Museum. By Carl W. Mitman.
Bulletin 128, List of North American Recent Mammals, 1923. By Gerrit S. Miller, jr.

Of the separate papers of the Contributions from the United States National Herbarium the following were issued:

Volume 22, part 7. The North American Species of Aristida. By A. S. Hitchcock.

Volume 22, part 8. New American Asteraceae. By S. F. Blake.
Volume 23, part 3. Trees and Shrubs of Mexico. (Oxalidaceae-Turneraceae.) By Paul C. Standley.
Volume 24, part 5. Economic Fruit-bearing Plants of Ecuador. By Wilson Popenoe.

Of the separates from the proceedings 11 were from volume 63, 19 from volume 64, and 9 from volume 65.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the Bureau of American Ethnology is under the direction of Mr. Stanley Searles, editor. During the year, there were published three bulletins and a list of publications of the bureau, as follows:

Bulletin 79. Blood Revenge, War, and Victory Feasts among the Jibaro Indians of Eastern Ecuador (Karsten). VII, 94 pp., 10 pls.
Bulletin 80. Mandan and Hidatsa Music (Densmore). XX, 192 pp., 19 pls., 6 figs.
Bulletin 81. Excavations in the Chama Valley, New Mexico (Jeancon). IX, 80 pp., 65 pls., 38 figs.
List of Publications of the Bureau of American Ethnology. 45 pp.

At the close of the year there were in press or in preparation five annual reports and two bulletins, as follows:

Thirty-eighth Annual Report. Accompanying paper: An Introductory Study of the Arts, Crafts, and Customs of the Guiana Indians (Roth).
Thirty-ninth Annual Report. Accompanying paper: The Osage Tribe: The Rite of Vigil (La Flesche).
Fortieth Annual Report. Accompanying papers: The Mythical Origin of the White Buffalo Dance of the Fox Indians; The Autobiography of a Fox Indian Woman; Notes on Fox Mortuary Customs and Beliefs; Notes on the Fox Society Known as "Those Who Worship the Little Spotted Buffalo"; The Traditional Origin of the Fox Society Known as "The Singing Around Rite." (Michelson.)
Forty-first Annual Report. Accompanying paper: Salish Basketry (Boas).
Forty-second Annual Report. Accompanying paper: Social Organization and Social Usages of the Indians of the Creek Confederacy (Swanton).
Bulletin 78. Handbook of the Indians of California (Kroeber).
Bulletin 82. Fewkes and Gordon Groups of Mounds in Middle Tennessee (Myer).

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the association to the Secretary of the Smithsonian Institution and are communicated by him to Congress as provided by the act of incorporation of the association.

Volume I of the Annual Report for 1919 and the supplemental volume to the report for 1920, entitled "Writings in American

History," were issued during the year. Volume II of the 1919 report, the reports for 1920 and 1921, and the supplemental volumes to the reports for 1921 and 1922 were in press at the close of the year.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Twenty-sixth Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with the law, on January 19, 1924.

SMITHSONIAN ADVISORY COMMITTEE ON PRINTING AND PUBLICATION

The editor has continued to serve as secretary of the Smithsonian advisory committee on printing and publication, to which are referred all manuscripts offered to the Institution and its branches for publication. The committee also makes recommendations to the secretary on matters relating to publication policy and economy in printing. Several recommendations were made during the year with a view to conserving as far as possible the inadequate amounts at present available to the Institution and its branches for printing and binding. Nine meetings were held during the year and 100 manuscripts acted upon.

Respectfully submitted.

W. P. True, *Editor.*

Dr. Charles D. Walcott,
Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDED JUNE 30, 1924

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds, receipts, and disbursements of the Institution and a statement of the appropriations by Congress for the National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, the Astrophysical Observatory, the International Catalogue of Scientific Literature, and the National Gallery of Art for the fiscal year ended June 30, 1924.

SMITHSONIAN INSTITUTION

Condition of the fund July 1, 1924

The sum of $1,000,000 deposited in the Treasury of the United States under act of Congress is a permanent fund, having been accumulated by the deposit of savings and bequests from time to time. Subsequent bequests and gifts and the income therefrom, when so required, are invested in approved securities. The several specific funds so invested are now constituted and classed as follows:

Consolidated fund

Avery fund	$29,557.52
Virginia Purdy Bacon fund	50,362.34
Lucy H. Baird fund	1,349.58
Chamberlain fund	34,952.27
Hamilton fund	500.00
Caroline Henry fund	1,074.00
Hodgkins general fund	37,226.57
Bruce Hughes fund	12,013.62
Morris Loeb fund	7,390.00
Lucy T. and George W. Poore fund	13,238.86
Addison T. Reid fund	4,919.00
Rhees fund	268.00
George K. Sanford fund	506.00
Smithson fund	1,468.74
Total consolidated fund	194,826.50
Charles D. and Mary Vaux Walcott research fund	11,520.00

The total amount of dividends and interest received by the Institution from the Freer estate during the year for all purposes was $234,446.50.

The itemized report of the auditor is filed in the office of the secretary.

Detailed survey of financial operations

Ordinary receipts:	
Cash balance on hand July 1, 1923	$11,531.63
Income from miscellaneous sources available for general purposes	55,874.72
International exchanges, repayments to the Institution for specific purposes	5,152.24
Total resources for ordinary purposes	72,558.59
Ordinary expenditures:	
Care and repair of buildings	7,667.19
Furniture and fixtures	1,299.07
General administration	26,697.91
Library	2,987.02
Publications (comprising preparation, printing, and distribution)	15,173.73
Researches and explorations	6,507.20
International exchanges	4,627.91
Total ordinary expenditures	64,960.03
Advances and repayments for field expenses and other temporary transactions during the year:	
Advances	15,938.75
Repayments	11,808.63
Difference	4,130.12

RECEIPTS AND EXPENDITURES FOR SPECIFIC OBJECTS

Receipts:	
Avery fund	$2,418.88
Virginia Purdy Bacon fund	2,607.76
Lucy H. Baird fund	67.64
Frances Lea Chamberlain fund	1,891.07
Caroline Henry fund	61.94
Bruce Hughes fund	659.56
Dr. W. L. Abbott research fund	243.29
Hamilton fund	178.39
Harriman trust fund	12,500.00
Hodgkins fund	6,000.00
Morris Loeb fund	1,689.65
Marsh-Darien expedition fund	1,000.00
National Gallery of Art building plans fund	11,000.00
North American Wild Flowers publication fund	18,050.00
Lucy T. and George W. Poore fund	3,660.59
Addison T. Reid fund	929.36
Rhees fund	49.59

Receipts—Continued.	
Research corporation, research fund	$1,250.00
W. A. Roebling, mineralogical fund	1,140.00
George K. Sanford fund	95.48
Charles D. and Mary Vaux Walcott fund	720.00
John A. Roebling solar research, etc., fund	24,168.79
General endowment fund	38.00
Researches in paleontology	1,500.00
Total	91,919.99
Expenditures:	
Dr. W. L. Abbott research fund, for field expenses, etc	622.22
Avery fund, invested	2,000.00
Virginia Purdy Bacon fund, invested and expended	2,340.00
Lucy H. Baird fund, invested	64.00
Chamberlain fund, for specimens	1,457.97
Harriman trust fund, for researches and specimens	10,185.20
Caroline Henry fund, invested	51.00
Hodgkins fund, for researches	3,551.06
Bruce Hughes fund, invested	935.00
Marsh-Darien expedition fund, expended	1,000.00
Morris Loeb fund, invested and expended	6,096.29
North American Wild Flowers publication fund, for expenses	10.50
Lucy T. and George W. Poore fund, invested and expended	3,297.78
Addison T. Reid fund, invested	500.00
Research Corporation, rocket investigation	1,000.00
Rhees fund, invested	30.00
John A. Roebling solar research, etc., fund, expended	24,150.07
W. A. Roebling mineralogical fund, expended	616.13
George K. Sanford fund, invested	55.00
Swales fund, for specimens	539.50
Total	58,501.72

RECEIPTS AND EXPENDITURES PERTAINING TO THE CHARLES L. FREER BEQUEST

Receipts:	
Interest, dividends, and miscellaneous receipts, including installments on Great Lakes Engineering Works, in liquidation	$234,446.50
Expenditures:	
Purchase of art objects, payment of salaries, and other operating expenses of the gallery, including reinvestment of funds	151,690.11
Investments in sinking fund, including interest	140,077.94
Total expenditures	291,768.05

SUMMARY

Receipts:	
Ordinary income for general objects, including cash balance at beginning of year	$72,558.59
Revenue and principal of funds conveyed for specific purposes, except the Freer bequest	91,919.99
Freer bequest	234,446.50
Cash recalled from time deposits	34,000.00
Total	432,925.08

Expenditures:	
General objects of the Institution	$64,960.03
Specific purposes, except Freer bequest	58,501.72
Advances for field expenses, etc	4,130.12
Freer bequest	291,768.05
Cash balance June 30, 1924	13,565.16
Total	432,925.08

All payments are made by check, signed by the Secretary of the Institution, on the Treasurer of the United States, and all revenues are deposited to the credit of the same account, except in some instances small deposits are placed in bank for convenience of collection and later are withdrawn in round amounts and deposited in the Treasury.

The practice of investing temporarily idle funds in time deposits has proven satisfactory. During the year the interest derived from this source, together with other similar items, has resulted in a total of $1,014.59.

The following appropriations were intrusted by Congress to the care of the Smithsonian Institution for the fiscal year 1924:

Bureau:		Appropriation
International Exchanges		$43,000
American Ethnology		44,000
International Catalogue of Scientific Literature		7,500
Astrophysical Observatory		15,500
National Museum—		
Furniture and fixtures	$20,000	
Heating and lighting	70,000	
Preservation of collections	312,500	
Building repairs	10,000	
Books	2,000	
Postage	500	
		415,000
National Gallery of Art		16,000
National Zoological Park		125,000
Increase of compensation		112,704
Printing and binding		77,400
Total		856,104

Respectfully submitted.

GEO. GRAY,
HENRY WHITE,
FREDERIC A. DELANO,
Executive Committee.

PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE FISCAL YEAR ENDED JUNE 30, 1924

ANNUAL MEETING, DECEMBER 13, 1923

Present: The Hon. William H. Taft, Chief Justice of the United States; Senator Henry Cabot Lodge; Representative Albert Johnson; Representative R. Walton Moore; the Hon. George Gray; the Hon. Henry White; Mr. Robert S. Brookings; Mr. Irwin Laughlin; Mr. Frederic A. Delano; and the secretary, Dr. Charles D. Walcott.

Judge Gray, as temporary chairman, called the meeting to order.

ELECTION OF A CHANCELLOR

The secretary said that the office of chancellor, to which Mr. Coolidge was elected by the board during his incumbency as Vice President, had been vacated by his elevation to the Presidency. Under the law organizing the Institution (sec. 5582), "The regents shall meet in the city of Washington, and elect one of their number as chancellor, who shall be the presiding officer of the Board of Regents. and called the chancellor of the Smithsonian Institution."

Senator Lodge offered the following resolution, which was adopted:

Resolved, That Chief Justice Taft be elected chancellor of the Smithsonian Institution.

APPOINTMENT OF REGENT

The secretary announced the reappointment of Senator Henry Cabot Lodge as a Regent.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE

Judge Gray, chairman of the executive committee, presented the following resolution, which on motion was adopted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1925, be appropriated for the service of the Institution, to be expended by the secretary with the advice of the executive committee, with full discretion on the part of the secretary as to items.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE

The secretary submitted in printed form the annual report of the executive committee, giving a statement of the financial condition of the Institution for the fiscal year ending June 30, 1923.

ANNUAL REPORT OF THE PERMANENT COMMITTEE

The secretary, on behalf of the permanent committee, read the report, as follows:

Hodgkins and Roebling funds.—Work is continuing steadily in the solar radiation researches being conducted on the Montezuma Mountain, Chile, under an annual grant of $5,000 from the Hodgkins fund. Mr. John A. Roebling has added generously to his contributions to aid the work at this station, and also at the one on Mount Harqua Hala, Ariz. These researches are being carried on under the direction of Dr. Charles G. Abbot, assistant secretary of the Institution and director of the Astrophysical Observatory.

Freer bequest.—The balance of the loan of $200,000 made to settle this estate was paid during the year.

In view of the fact that the Freer Foundation is invested entirely in Parke, Davis & Co.'s stock, the permanent committee took up the matter of safeguarding its principal and income; and, after careful consideration, decided upon what may be termed a sinking fund, by which that part of the income in excess of 6 per cent on the value of the foundation at the time of Mr. Freer's death is to be reinvested in high-class securities and real-estate mortgages until an amount equal to the original foundation is reached.

Poore bequest.—Negotiations are now pending for the sale of several of the lots in Lowell, Mass., received under this bequest, which will net the Institution about $1,500. The remaining lots will be disposed of as opportunity offers. Since the last meeting of the board the city of Lowell has agreed to abate the taxes on this property.

All the other funds previously detailed are in sound condition and are slowly but steadily increasing in volume through the addition of their earnings to the principal.

The consolidated fund, which comprises bequests and gifts to the Institution in addition to the $1,000,000 deposited in the United States Treasury in accordance with the organic act, now amounts to $196,570.28.

SECRETARY'S ANNUAL REPORT

In submitting his annual report of the operations of the Institution for the fiscal year ending June 30, 1923, the secretary stated that the publications of the Institution are its chief means of carrying out one of its primary functions, the "diffusion of knowledge among men." Since the last annual meeting of this board, in December 1922, the Institution and its branches have issued a total of 98 publications, both volumes and pamphlets. Of this number, 49 were published by the Institution proper, 44 by the National Museum, 4 by the Bureau of American Ethnology, and 1 by the National Gallery of Art. A large part of the edition of each of these publications is distributed free to libraries, educational institutions, and specialists throughout the world. The nation-wide popularity of the Smithsonian Annual Report is attested by the fact that a cataloguer in the office of the Superintendent of Documents has placed it first among all public documents in number of requests from libraries to receive it. In connection with the publications, the secretary called attention to the inadequacy of the funds available for printing.

ANNUAL REPORT OF THE NATIONAL GALLERY OF ART COMMISSION

The third annual meeting of the National Gallery of Art Commission was held December 11, 1923. The resignation of Mr. Daniel Chester French as chairman of the commission was received and accepted with regret, and Mr. Gari Melchers was elected chairman.

The report of the secretary of the commission and director of the gallery presented a review of the activities of the gallery for the year, and reports of the standing and special committees followed.

In response to the resolution submitted by the Regents, February 8, 1923, requesting the commission's consideration of the suggestion that a museum of architecture be founded in connection with the Institution, the following resolution was adopted:

Resolved, That the National Gallery of Art Commission recommend to the Regents of the Smithsonian Institution the inclusion of a division of historical architecture in the National Gallery of Art. The division should seek to establish standards in architecture, furniture, and landscape architecture for the benefit of students and others interested in the preservation of the historic buildings of America.

The important problem of a national gallery building was considered and assurance given that the building plans would be provided for in the near future.

A resolution was passed recommending to the Board of Regents the election of Mr. James E. Fraser and Mr. Joseph Breck to fill vacancies caused by the resignation of Mr. Daniel Chester French and the declination of Mr. Denman W. Ross.

The commission also voted to recommend to the Board of Regents the election for the full term of four years of Messrs. Edwin H. Blashfield, Joseph H. Gest, and Frank Jewett Mather, jr., their two-year terms having expired.

After discussion, the following resolutions were adopted:

Resolved, That the Board of Regents of the Smithsonian Institution approves in principle the recommendation of the National Gallery of Art Commission that a division of historical architecture be established in connection with the National Gallery of Art.

Resolved, That the Board of Regents of the Smithsonian Institution hereby elects Mr. James E. Fraser and Mr. Joseph Breck as members of the commission, to fill the vacancies caused by the resignation of Mr. Daniel Chester French and the declination of Mr. Denman W. Ross, respectively.

Resolved, That the Board of Regents of the Smithsonian Institution hereby elects Messrs. Edwin H. Blashfield, Joseph H. Gest, and Frank Jewett Mather, jr., as members of the National Gallery of Art Commission for the full term of four years, their present two-year terms having expired.

MEMORIAL TO ALEXANDER GRAHAM BELL

On behalf of the executive committee, the secretary submitted the following report:

DECEMBER 13, 1923.

GENTLEMEN: The executive committee, designated by the Board of Regents at its annual meeting on December 14, 1922, to prepare for the records of the

board a brief memorial commemorating the life and work of Doctor Bell, a former Regent of the Institution, begs to submit the following:

"Alexander Graham Bell, doctor of philosophy, doctor of science, a member of the Board of Regents of the Smithsonian Institution, was born March 3, 1847, at Edinburgh, Scotland.

"Doctor Bell was appointed a Regent on January 24, 1898, and served until February 20, 1922. During this entire period of 24 years he was a member of the executive and permanent committees of the board, where his sound judgment and ripe experience were of great assistance to his associates.

"Doctor Bell's interest in the work of the Smithsonian Institution began many years before his appointment as Regent, his studies in acoustics particularly having been the subject of many consultations with Secretary Henry. Later, in 1887, when Samuel P. Langley was elected secretary, he resumed his intimate though unofficial relations, as evidenced by his gift of $5,000 in 1891 in connection with the development of the Astrophysical Observatory, and his helpful interest in the aerodynamical researches of Secretary Langley. It was Doctor Bell who made the only successful photograph of the Langley model in its first flight, May 6, 1896, though at this time he was independently conducting exhaustive experiments in this new science.

"After he became a Regent, Doctor Bell was likewise active in forwarding the work of the Institution in many directions. Among the notable matters that particularly engaged his personal attention were:

"His voluntary service in transferring the remains of James Smithson, founder of the Institution, from the English cemetery at Genoa, Italy, to their final resting place in the Smithsonian Building;

"His suggestion that resulted in the establishment of the Langley medal in connection with the development of aviation;

"His labors as a member of the committee on award of this medal; and

"His historical address upon Secretary Langley's discovery of the principles of aviation, delivered February 10, 1910, at the presentation of the Langley medal to its first recipients, the Wright brothers.

"Doctor Bell had reached a high eminence in the scientific world long before his connection with the Institution. The history of his achievements is too well known to be repeated here; but it is proper to mention his invention of the telephone; his great work in the physiology of human speech that made it possible for him to teach the deaf to speak; and his invention of the telephone probe for detecting the presence of bullets in the human body. He was a believer in geographic research and was one of the founders of the National Geographic Society. He was a member of the National Academy of Sciences, and of other national and international learned organizations, and was the recipient of many medals, degrees, and other honors as a man of great scientific achievement.

"Doctor Bell had a strong physique, but the strain of many years of intense endeavor made itself felt, and he found it necessary to give up much of his work in the last year or two of his life. His weakness increased until the end came on August 2, 1922, at his summer home near Baddeck, Nova Scotia.

"Alexander Graham Bell was one of the outstanding men of his time, and his death brought a highly useful career to a close."

Respectfully submitted.

GEORGE GRAY,
HENRY WHITE,
FREDERIC A. DELANO,
Executive Committee.

On motion, the memorial was approved and ordered to be spread upon the records of the board.

RADIO CELEBRATION OF JOSEPH HENRY'S BIRTHDAY

The secretary called attention to the birthday of Henry, first secretary of the Smithsonian Institution, which is to be celebrated by radio on December 17. The occasion will be observed by appropriate addresses broadcast from the stations at Troy and Schenectady, N. Y.

Joseph Henry was born at Albany on December 17, 1799. His first studies in electricity began in 1827, while he was a teacher in the Albany Academy, and in the course of his researches he transformed an inefficient piece of electrical apparatus into the powerful electromagnet, and laid the foundation for the most important discoveries of the century. He made two distinct forms of magnets; one capable of excitation at a distance, called the "intensity magnet," and the other having possibilities of infinite development of strength, which he named the "quantity magnet."

Before Henry, the strongest form of electromagnet known could lift only 9 pounds, but after a few months of experiment he produced one which sustained 39 pounds. This was successively followed by others which could support 750, 2,300, and 3,500 pounds. The intensity magnet was the forerunner of the modern telegraph, and in 1831 Henry transmitted a current through a considerable length of wire and succeeded in ringing a bell. On December 17, 92 years later, this identical bell will be rung during the ceremonies, and the sound will be heard by listeners throughout the United States and probably across the Atlantic. The bell is now a treasured relic in the New York State Museum at Albany.

When the Smithsonian Institution was founded, Joseph Henry was selected as its first secretary, and his plan of organization for the new Institution was carried out. His broad-minded policies enabled the Institution to become firmly established, and through its stated purpose, "the increase and diffusion of knowledge among men," to attain a world-wide reputation as a center of scientific activity in America. During Henry's term as secretary (1846–1878) he inaugurated the system of daily meteorological observations and reports which developed into the present United States Weather Bureau.

EXPEDITIONS

Archeological expedition to China.—The archeological expedition sent to China last February under the joint auspices of the Freer Gallery of Art and the Museum of Fine Arts, Boston, and under the immediate direction of Mr. Carl W. Bishop, associate curator of the Freer Gallery, seems already to have paved the way for a far better approach to the problems of Chinese archeology than has ever existed before. Mr. Bishop's first duties have been to make clear to

interested Chinese the spirit and purpose of the expedition, to establish among them a feeling of confidence in its integrity and ability, and to organize a self-sustaining archeological society of native scholars which should have the official sanction and support of the Chinese Government in all its undertakings. These delicate and difficult tasks Mr. Bishop has prosecuted with an extraordinary degree of skill and success. The archeological society, with headquarters in Peking and a membership composed of the most influential scholars and Government officials, has already made arrangements with the authorities for the expedition to undertake the excavation of two highly important sites, on the understanding that while the records and reports of the operations shall be at its disposal the material "finds" shall be equally divided between the Chinese Government and the expedition.

Mr. Bishop also has been fortunate enough to acquire for the expedition several fine examples of Chinese art, but it is his success in establishing for the first time a truly cooperative relationship between Chinese and American archeologists which must be thought to justify the expedition, even had it accomplished nothing else.

Biological expedition to China.—Through the continued generosity of Dr. William L. Abbott, of Philadelphia, an expedition to the Yangtze Valley, in China, was arranged for the purpose of obtaining specimens of vertebrates peculiar to that locality, and Mr. Charles M. Hoy, who had previously explored in the central China region, left the United States for this purpose in December, 1922. I greatly regret to report that in September, 1923, Mr. Hoy was seized with an acute attack of appendicitis and that his death occurred on the 6th of that month. This is a serious loss to the Museum, but, thanks to Doctor Abbott, arrangements have been made to turn Mr. Hoy's collecting and field outfit over to the Rev. D. C. Graham, of Suifu, from whom several valuable sendings have been received, and who is contemplating extensive excursions into the more interesting and little known parts of Szechwan.

Doctor Abbott's generosity has been frequently called to the attention of the board, large contributions having been made by him for the expeditions to Borneo, Celibes, Australia, and the present ones in China, in addition to which he has given largely from the results of his personal efforts in Haiti and elsewhere.

Alberta and British Columbia.—During the summer and fall of 1923, the secretary of the Institution carried on geological field work in the Canadian Rockies in this region. This work was in continuation of the operations of the previous year in the main range and the western minor ranges that form the great eastern wall of the Columbia River Valley from Golden southward to Kootenay River.

The season was favorable for geological work, and a large supply of material was secured which will be studied later.

REORGANIZATION OF GOVERNMENT DEPARTMENTS

The secretary spoke of the proposed reorganization of Government Departments, under which it was proposed to include the Smithsonian Institution in a Department of Education.

The following considerations were mentioned among others:

1. A large part of the success which the Institution has had in carrying on and aiding research work has been due to the fact that varying political fortunes have no effect on its direction. Its secretary is selected by the Board of Regents provided for in the act creating the Institution. It is thus enabled to pursue a definite and continuous policy which is unaffected by political changes.

2. During the 77 years of its existence as an independent establishment the Smithsonian Institution has acquired a reputation and standing throughout the civilized world as a center of scientific endeavor in America. To place it in the position of a subordinate member of an educational department would impair its standing and so relegate it to an unimportant position far from the intention of its founder, of the act of Congress establishing the Institution, and of those who have since made large gifts to it, principally because it was independent of political and sectarian domination.

3. Freedom of action, one of its chief assets in various scientific activities and in international undertakings, would be entirely lost if the Institution were placed under the administration of a political unit of the Government.

There was a very general expression of disapproval of the proposed plan.

NEED OF AN ADDITIONAL ASSISTANT SECRETARY

The secretary stated that there was urgent need for the provision for an assistant secretary of the Smithsonian Institution, to be charged, under the direction of the secretary, with the administration of the National Museum, Art Galleries, Zoological Park, and the Bureau of American Ethnology, and with such other duties as may from time to time be assigned to him by the secretary. The care and development of these four branches involve the employment of highly trained specialists and their assistants, and the coordination of the activities of each group with those of the other groups and also with those of research and technical workers in the great Government bureaus, such as those of the Agriculture, Interior, and Commerce Departments, and the great research institutions and university laboratories throughout our country and in foreign lands. Such coordination requires the initiative, guidance, and constant supervision of an able, well-trained, and experienced broadly cul-

tured scientific man who must also have considerable administrative ability.

After full discussion, on motion, the following resolution was adopted:

Resolved, That the Board of Regents of the Smithsonian Institution declare the need of an additional assistant secretary of the Smithsonian Institution, whose salary shall be provided for by congressional appropriation; the said assistant secretary to be charged with the administration, under the direction of the secretary, of the National Museum, Art Galleries, Zoological Park, and Bureau of American Ethnology, and with such other duties as may from time to time be assigned to him by the secretary.

FINANCIAL OUTLOOK

The secretary spoke of the urgent need of a larger endowment for the institution; that work of the most important character was being held back for lack of funds to carry it on.

The secretary presented a supplemental statement giving a brief résumé of the activities of the various branches of the Institution during the past fiscal year. These will be described more fully in the annual report for 1924.

REGULAR MEETING, FEBRUARY 14, 1924

Present: Senator A. Owsley Stanley; Representative R. Walton Moore; Representative Walter H. Newton; Mr. Charles F. Choate, jr.; Mr. Robert S. Brookings; Mr. Irwin B. Laughlin; and the secretary, Dr. Charles D. Walcott. Mr. Choate presided.

APPOINTMENT OF REGENTS

The secretary announced that the Speaker of the House had reappointed Messrs. Albert Johnson and R. Walton Moore as Regents and had filled the vacancy caused by Mr. Greene's election to the Senate by the appointment of Mr. Walter H. Newton, of Minnesota.

BUILDING FOR ART AND HISTORY

The secretary spoke of the proposed building for the National Gallery of Art and History, displaying sketch plans of its general outline and its location, stating that it comprehended a building somewhat over 500 feet long by 300 feet deep, with an elevation of about 80 feet. He quoted the act granting the use of the site on B Street NW., between Seventh and Ninth Streets.

ARCHITECT FOR ART AND HISTORY BUILDING

At the annual meeting of the board, on December 13, 1923, the National Gallery of Art Commission reported that provision would

be made in the near future for the preparation of building plans for the proposed new building. The commission met recently and reported that funds for the employment of an architect had been provided by private contributions from 13 persons to the amount of $11,000. The commission, having canvassed the names of a number of American architects who had been suggested as qualified to prepare the plans, recommended the selection of Mr. Charles A. Platt, whose selection was approved by the Board of Regents.

After discussion, a motion was adopted appointing Messrs. White and Delano, of the Board of Regents; Messrs. Adams, Melchers, and Gest, of the commission; and the secretary of the Institution as a committee to collaborate with the architect in the preparation of the plans for the new building.

ACKNOWLEDGMENT

The secretary read a letter from Mr. Gilbert H. Grosvenor expressing the appreciation of the family of the late Dr. A. Graham Bell for the memorial adopted by the board at the annual meeting on December 13 last.

SPECIAL MEETING, JUNE 3, 1924

Present: Senator Henry Cabot Lodge; Representative Albert Johnson; Representative Walter H. Newton; the Hon. George Gray; Mr. Henry White; and the secretary, Dr. Charles D. Walcott. Senator Lodge presided.

AUTHORITY FOR CALLING SPECIAL MEETINGS

The secretary explained that the fundamental act provides for calling special meetings at the request of three Regents, and that this meeting had been called by the executive committee and approved by the chancellor.

ADDITIONAL ASSISTANT SECRETARY

The secretary brought up the matter of an additional assistant secretary, explaining that at the annual meeting on December 13, 1923, the Board of Regents adopted a resolution declaring the need of such an officer, which had been communicated to the President. With the President's approval, the Director of the Budget submitted the request to Congress, after the Personnel Classification Board had put the position in class 6. The Appropriations Committee fixed the annual salary at $6,000, and the item was now included in the independent offices bill under "Smithsonian Institution."

ESTIMATES FOR NATIONAL ZOOLOGICAL PARK

The secretary stated that—

Estimates are at present submitted by the Smithsonian Institution to the District Commissioners (a copy is forwarded direct to the Bureau of the Budget) for inclusion in the District of Columbia estimates. The commissioners forward these to the Bureau of the Budget with all other estimates intended for the District of Columbia appropriation bill. The Director of the Budget returns the complete estimates to the District Commissioners with a statement as to the maximum figures that will be allowed the District for the whole bill. It is the duty of the commissioners to reduce the estimates to this figure and return to the Bureau of the Budget.

The District Commissioners have their own troubles and urgent requirements, and, since the allotment made is far under their own estimates, it is only natural that they should give first consideration to items for which they are directly responsible—streets, sewers, fire and police protection, schools, etc. In the three years since the Zoological Park has been included in the District bill, no hearings of any kind have been given the Institution on the Zoo estimates by the District Commissioners. For two years the estimates were simply reduced to the figures for the previous year and returned to the Budget without the Institution even knowing the amount thus approved by the commissioners. The commissioners even changed all figures in the detailed statement accompanying the estimates to agree exactly with those of the preceding year, thus presenting to the Budget and later to Congress useless and misleading figures in explanation of the proposed expenditures.

I do not think that the District Commissioners should be given the arbitrary power to control the finances of the National Zoological Park, which is placed by law under the direction of the Smithsonian Institution.

It should be practicable to include the estimate for the Zoological Park in the independent offices bill along with the other estimates for Government bureaus administered under the direction of the Board of Regents of the Smithsonian Institution. The latter are held responsible for the care and administration of the park and there should be no divided responsibility in matters bearing upon its administration.

After discussion, on motion of Mr. Newton, the following resolution was adopted:

Resolved, That it is the sense of this meeting of the Board of Regents that the appropriation for the National Zoological Park should be carried in the independent offices bill, as are the items for the other Government bureaus administered under the direction of the Board of Regents of the Smithsonian Institution.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1924

ADVERTISEMENT

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1924.

THE ORIGIN OF THE SOLAR SYSTEM[1]

By J. H. Jeans

Secretary, Royal Society of London

[With 5 plates]

The astronomer of to-day has at his disposal telescopes which range in aperture from his naked eye, of aperture about one-fifth of an inch, up to the giant Mount Wilson telescope of more than 100 inches. If we lived in the midst of a uniform infinite field of stars, or in a field which was uniform as far as our telescopes could reach, the numbers of stars visible in different telescopes would be proportional to the cubes of their apertures.

In actual fact our naked eyes reveal about 5,000 stars; with a one-inch telescope this number is increased to about 100,000, with a 10-inch to 5,000,000, and with the 100-inch telescope to perhaps 100,000,000. These numbers increase much less rapidly than the cubes of the apertures. We conclude that we are not surrounded by an infinite uniform field of stars. We live in a finite universe, which thins out quite perceptibly within distances reached by telescopes of very moderate size. It is estimated that the whole universe consists of some 1,500 million stars, our sun being not very far from the center of the system.

Imagine the various celestial objects in this universe arranged according to their distance from us. Disregarding altogether bodies which are much smaller than our earth, we must give first place to the planets Venus and Mars, which approach to within 26 and 35 millions of miles, respectively. Next comes Mercury with a closest approach of 47 million miles, and the sun at 93 million miles. The remainder of the planets follow at distances ranging up to 2,800 million miles, the radius of the orbit of Neptune.

But now comes a great gap. The first objects beyond this gap are the faint star Proxima Centauri at a distance of 24 million million miles, or more than 8,000 times the distance of Neptune, and, close to it, α Centauri at 25 million million miles. Next in order come the faint red star Munich 15,040 at 36 million million

[1] Discourse delivered at the Royal Institution of Feb. 15. Reprinted by permission from the supplement to Nature, Mar. 1, 1924.

miles, and another faint star Lalande 21,185 at about 47 million million miles. Thus our nearest neighbors among the stars are at almost exactly a million times the distances of our nearest neighbors among the planets. After these comes Sirius, the brightest star in the sky, at 50 million million miles. From here on there is a steady succession of objects until we reach distances of more than 20,000 times that of Sirius; but long before these distances are reached other objects, spiral and spheroidal nebulæ, and ultimately star clusters, are found to be mingled with the stars. The furthest object the distance of which is known with any accuracy is the star cluster N. G. C. 7006, which Shapley estimates to be 25,000 times as distant as Sirius. This cluster is so remote that its light takes 200,000 years to reach us; even for light to cross the cluster takes hundreds of years. To all appearances the star cloud N. G. C. 6822 is still more remote. According to Shapley, its distance is about 6 million million million miles, a distance which light takes a million years to traverse. So far as is known at present, this brings us to the end of our universe, or perhaps I ought to say it brings us back to the beginning.

It is no easy matter to get all these different distances clearly into focus simultaneously, but let us try. The earth speeds round the sun at about twenty miles a second; in a year it describes an orbit of nearly 600 million miles circumference. If we represent the earth's orbit by a pinhead or a full stop of radius one-hundredth of an inch, the sun will be an invisible speck of dust, and the earth an ultramicroscopic particle one-millionth of an inch in diameter. Neptune's orbit, which incloses the whole of the solar system, will be represented by a circle the size of a threepenny piece, while the distance to the nearest star, Proxima Centauri, will be about 75 yards and that to Sirius about 160 yards. On this same scale the distance to the remote star cluster N. G. C. 7006 is 2,400 miles and that to the star cloud N. G. C. 6822 about 12,000 miles, so that roughly speaking the whole universe may be represented by our earth.

It thus appears that we are on this occasion to discuss the origin and past history of a system which bears the same relation to the universe as a whole as does a threepenny piece to our earth. Why are we so interested in this particular threepenny piece? Primarily because, although a poor thing, it is our own, or at least one particle of it, one-millionth of an inch in diameter, is our own. But there is a historical reason of a less sentimental kind. We have already noticed the immensity of the gap between our system and its nearest neighbors. As regards astronomical knowledge this gap has taken a great deal of crossing. Well on into last century, human knowl-

edge of the further side of this gap was infinitesimal; the stars were scarcely more than points of light, described as "fixed stars." In those days the problem of cosmogony reduced perforce to the problem of the origin of our own system.

Recent research has changed all this, and the modern astronomer has a very extensive knowledge of the nature, structure, and movements of the various bodies outside our system. The cosmogonist of a century ago could assert that the solar system had evolved in such and such a way, and need have no fear of his theories being upset by comparison with other systems. But if I put before you now a theory of the origin of our system, you will at once inquire as to the behavior of the 1,500 million or so of systems beyond the great gap. Are they following the same evolutionary course as our own system, and, if not, why not? It may be well to consider these other systems first.

Among these 1,500 million or so of objects there are certain comparatively small classes the nature and interpretation of which are still enigmatical—the planetary nebulæ, the Cepheid variables, the long-period variables such as Mira Ceti, and a few others. Apart from these, practically all known bodies can be arranged in one single continuous sequence. The sequence is approximately one of increasing density; it begins with nebulæ of almost incredible tenuity and ends with solid stars as dense as iron. There is but little doubt that the sequence is an evolutionary one, for the laws of physics require that as a body radiates heat its density should increase, at least until it can increase no further. Let us begin our survey at the furthest point back to which we can attain on this evolutionary chain—the nebulæ.

After the enigmatical "planetary" nebulæ have been excluded, the remaining nebulæ fall into two fairly sharply defined classes, which may be briefly described as regularly and irregularly shaped nebulæ.

The irregularly shaped nebulæ comprise such objects as the great nebula in Orion, and the nebulosity surrounding the Pleiades. Until quite recently these irregular nebulæ were supposed to be of great evolutionary importance. It was noticed that they were usually associated with the very hottest stars; whence arose a beautifully simple cosmogony asserting that these very hot stars were the immediate products of condensation of the nebulæ, and that their after life consisted merely of a gradual cooling until they got quite cold. This cosmogony was too simple to live for long—it was buried some ten years ago by the researches of Russell, Hertzsprung, and others. Thanks to these researches, we now know that the very hot stars associated with irregular nebulæ, so far from being newly born, are standing at the summit of their lives awaiting their decline into old age.

A mass of hot gas isolated in space radiates heat, and this causes it to contract. If the mass radiated without contracting, it would, of course, get cooler; on the other hand, if it contracted without radiating, it would get hotter. But when radiation and contraction are proceeding together it is not obvious without mathematical investigation which of the two tendencies will take command. In 1870 Homer Lane showed that a mass of gas of density low enough for the ordinary gas laws to be approximately obeyed, will in actual fact get hotter as it radiates heat away. Cooling does not set in until a density is reached at which the gas laws are already beginning to fail—that is to say when liquefaction and solidification are already within measurable distance. Thus we see that maximum temperature is associated with middle age in a star, the age at which the star may no longer be regarded as a perfect gas. At this period of middle age the surface temperature of the star may be anything up to about 25,000° C., while the temperature at its center will amount to millions of degrees. Its average density will probably be something like one-tenth of that of water. It is still not known why stars at this special maximum temperature are so commonly associated with irregular nebulæ. Possibly it may be that only stars at the very highest temperatures are capable of lighting up surrounding nebulosity which would otherwise remain invisible. Be this as it may, it is fairly clear that these irregular nebular masses are not an essential part of the evolutionary chain. They are probably mere by-products, and as such may be dismissed from further consideration.

We turn to the nebulæ of regular shape. A great number of these appear as circles or ellipses, some as ellipses drawn out at the ends of their major-axes, sometimes almost to sharp points. An example of this last type of figure is shown in Plate 1, Figure 1 (Nebula N. G. C. 3115).

A number of these regular-shaped nebulæ have been examined spectroscopically, and in every case have been found to be rotating with high velocities about an axis which appears in the sky as the shortest diameter of the nebula. The mathematician can calculate what configurations will be assumed by masses of tenuous gas in rotation. If rotation were entirely absent the mass would, of course, assume a spherical shape. With slow rotation its shape would be an oblate spheroid of low ellipticity—an orange-shaped figure like our earth. At higher rotations the spheroidal shape is departed from, the equator bulging out more and more until finally, for quite rapid rotation, the shape is approximately that of a double convex lens having a sharp circular edge for its equator, the shape, in fact, exhibited by the nebula shown in Plate 1, Figure 1. The whole

succession of figures, if looked at along all possible lines of sight, will exhibit precisely the series of shapes which are found to be exhibited by the regular nebulæ under discussion. There are, then, good grounds for conjecturing that these nebulæ are rotating masses of gas; but we can test this conjecture further before finally accepting it.

As a mass of gas radiates its energy away it must shrink. If it is in rotation, its angular momentum will remain constant, and the shrunken mass can only carry its original dose of angular momentum by rotating more rapidly than before. This conception, which formed the corner-stone of the cosmogonies of Kant and Laplace, is still of fundamental importance to the cosmogonist of to-day. Thus every nebula, as it grows older, will rotate ever more and more rapidly and, barring accidents, will in due course reach the configuration shown in Plate 1, Figure 1. This configuration marks a veritable landmark in the evolutionary path of a nebula. Until this configuration is reached the effect of shrinkage can be adjusted, and is adjusted, by a mere change of shape; the mass carries the same angular momentum as before, in spite of its reduced size, by the simple expedient of rotating more rapidly, and restores equilibrium by bulging out its equator. But mathematical analysis shows that this is no longer possible when once this landmark has been passed. Further shrinkage now involves an actual break-up of the nebula, the excess of the angular momentum beyond that which can be carried by the shrunken mass being thrown off into space by the ejection of matter from the equator of the nebula.

We have so far spoken of the nebular equator as being of circular shape, as it undoubtedly would be if the nebula were alone by itself in space. But an actual nebula must have neighbors, and these neighbors will raise tides on its surface, just as the sun and moon raise tides on the surface of the rotating earth. Whatever the neighbors are, there will always be two points of high tide antipodally opposite to one another, and two points of low tide intermediate between the two points of high tide. Thus the equator, instead of being strictly circular, will be slightly elliptical.

If the equator of the nebula had been a perfect circle, and if the nebula had been in all respects symmetrical about its axis of rotation, the ejection of matter would have started from all points of the equator simultaneously. Indeed, there could be no conceivable reason why it should start at one point rather than at any other point. But in nature we do not expect to find perfect balances of this kind; if the main factors are of exactly equal weight some quite minor factor invariably intervenes to turn the balance in one direction or another. In the present problem there could be no

choice as between one point of the equator and another if the various minor factors were absent, but when these minor factors come into play, a discrimination at once takes place. Assuming, as seems likely, that the tidal irregularities are the minor factors which determine the choice of points for the ejection of matter, mathematical investigation shows that the ejection of matter will take place from the two antipodal points on the equator at which the tide is highest. The equator being slightly elliptical, these points are of course the ends of its major-axis. After the nebula has passed its critical landmark, shown in Plate 1, Figure 1, its shape ought to be similar to the lenticular figure which formed the landmark, but with the additional feature of matter streaming out from two antipodal points on its equator.

This describes exactly what is observed in the spiral nebulæ. Plate 1, Figure 2 (N. G. C. 5866) shows a nebula in which the ejection of matter is just beginning; we notice the bulge along the equator and the dark band which we may assume represents ejected matter which is already cooling. Plate 2, Figure 1 (N. G. C. 4594) exhibits a more advanced state of development; and Plate 2, Figure 2 (N. G. C. 891), a still later one in which the ejected matter already dwarfs the central nucleus in size, although probably not in total mass.

In all these figures we are looking at the nebulæ very approximately edge-on. Plate 3, Figure 1 (M. 51) shows the well-known "whirlpool" in Canes Venatici, a nebula which may be very similar physically to that shown in Plate 2, Figure 2, but we see it face on; we are looking along its axis of rotation. Again the central nucleus occupies only a small part of the picture. Plate 3, Figure 2 (M. 101) and Plate 4, Figure 1 (M. 81) shows two nebulæ, the evolution of which has proceeded still further, so much so that in the last of these there is very little nucleus left, and by far the greater part of what we see is what we believe to be ejected matter.

In both of these last two nebulæ it will be seen that the arms of ejected matter proceed from two antipodal points, exactly as required by dynamical theory. So far we have spoken of the matter in these arms as ejected matter because theory has suggested this interpretation, but we need not be satisfied with theory; there is very direct observational evidence on the point. Various astronomers, especially Van Maanen, have detected motion in the arms of many nebulæ, including the three shown in Plate 3, Figures 1 and 2, and Plate 4, Figure 1. Their observations show that the arms are in truth jets of matter coming out of the nucleus. Plate 4, Figure 2 shows the motion found by Van Maanen for about 100 points in the nebula M. 81, the arrows showing the motion in a period of 1,300

years,[2] and the measures on the various other nebulæ show substantially similar results; you will see that there is little room for doubting that the arms consist of matter flowing out of the nucleus. On measuring the actual velocities of flow it is found that in nebula M. 51 (pl. 3, fig. 1) a particle of the jet makes a complete revolution around the nucleus in about 45,000 years; in M. 81 (pl. 4, fig. 1) the corresponding figure is about 58,000 years, and in M. 101 (pl. 3, fig. 2) about 85,000 years. From these figures it is possible to estimate the density of the matter in the nucleus. It is found that the densities must be of the order of 10^{-16} gm. per cubic centimeter, a figure representing a vacuum more perfect than any obtainable in the laboratory. The small amount of gas in an ordinary electric light bulb, if spread out through St. Paul's Cathedral, would still be something like 10,000 times as dense as the nucleus of a spiral nebula.

The nebula shown in Plate 2, Figure 2 exhibits a lumpy or granulated appearance in its arms. In M. 51 (pl. 3, fig. 1) this takes the form of pronounced condensations, and in the outer regions of M. 101 (pl. 3, fig. 2) and M. 81 (pl. 4, fig. 1) these condensations have further developed into detached and almost star-like points of light.

When gas is set free out of an ordinary nozzle into a vacuum it immediately spreads into the whole of the space accessible to it. Why then does not the jet of gas shot off from the equator of the nebula do the same? The explanation is to be found in the gigantic scale on which this latter process takes place. As we increase the scale of the phenomenon the mutual gravitational attraction of the particles of gas becomes of ever greater importance until finally, by the time nebular dimensions are reached, gravitation overcomes the expansive influence of gas pressure and is able to hold the jet together as a compact stream. But, as soon as this happens, dynamical theory predicts that a further phenomenon ought to appear. As regards the distribution of density along the filament, the influence of gas-pressure is in the direction of keeping the density spread out uniformly, while that of gravitation is toward making the stream condense with compact globules. When nebular dimensions are reached the latter tendency prevails, and the issuing jet of gas breaks up into drops much as a jet of water issuing from a nozzle does, although for a very different physical reason. In the photographs reproduced in Plate 2, Figure 2; Plate 3, Figures 1 and 2; and Plate 4, Figure 1, we can trace this process going on.

Dynamical theory not only predicts that these globules of gas must form, but also enables us to calculate their size, mass, and

[2] The points surrounded by small circles are stars which are believed to have no physical connection with the nebula.

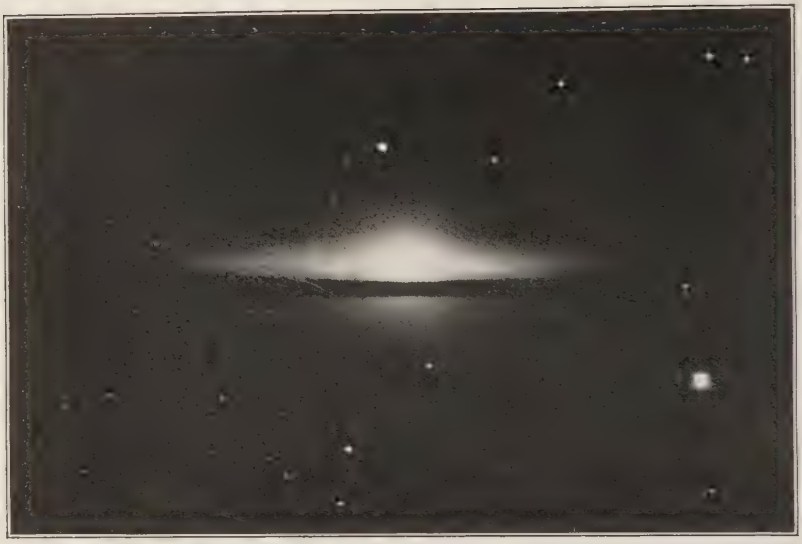
distance apart. A comparison between their distance apart, as calculated in kilometers, and their angular distance apart, as observed in the sky, leads at once to an estimate of the distance of the nebula to which they belong. It is gratifying to find that estimates of nebular distances made in this way are in good agreement with estimates made in other ways. The calculation of the masses of these condensations leads to a still more interesting and significant result. In every nebula for which the calculation can be made, the calculated mass of a single condensation proves to be approximately equal to the mass of the average star.

This gives, I believe, the key to the evolutionary process we have been considering—we have been watching the creation of the stars. In Plate 1, Figure 1 we saw the raw material—a gaseous mass of extreme tenuity, already moulded, as a result of shrinkage and consequent increase of rotation, to the stage at which disintegration is about to commence. Further shrinkage takes place, and in Plate 1, Figure 2, and Plate 2, Figure 1 we see the ejection of jets of gas from which the future stars will in due course be made. In Plate 2, Figure 2, and Plate 3, Figure 1 individual stars are beginning to form, although at present only as vague condensations in what is still a continuous nebular mass. Finally, the outermost parts of Plate 3, Figure 2, and Plate 4, Figure 1 show us the finished product—separate masses, although still far more tenuous than ordinary stars, starting off on their independent existences. Each of these masses will go through the changes we have already briefly described. It will contract, getting hotter in doing so, until it reaches a maximum temperature just as the gas laws are beginning to fail, after which it cools and contracts into a dead dark mass.

The family of stars born out of a single nebula may be millions in number. They may either mingle with the general mass of the stars or, if the original nebula was sufficiently remote from the main universe of stars, may form a separate colony by themselves. In illustration of the former alternative, numbers of groups of stars are known—e. g. the Pleiades, the stars of the Great Bear—in which all the members have a common velocity and, generally speaking, similar physical constitutions also. All the stars of any such group are voyaging through space together, and have obviously done so since they first came into being. The alternative possibility of a family of stars forming a detached colony by themselves is perhaps exemplified in the so-called "globular" star-clusters, such as the well-known cluster in Hercules (pl. 5). These are globular only in name, for Shapley has found that they are of an elliptical structure, showing symmetry about a plane precisely as might be expected if they were the final product of a rotating nebula.

1. REGULAR SHAPED NEBULA (N. G. C. 3115)

2. REGULAR SHAPED NEBULA (N. G. C. 5866) WITH BAND OF DARK MATTER ON EQUATOR



1. REGULAR SHAPED NEBULA (N. G. C. 4594) WITH RING OF DARK MATTER SURROUNDING EQUATOR

2. SPIRAL NEBULA (N. G. C. 891) SEEN EDGE ON

1. SPIRAL NEBULA IN CANES VENATICI (M. 51)

2. SPIRAL NEBULA IN URSA MAJOR (M. 101)

1. SPIRAL NEBULA IN URSA MAJOR (M. 81)

2. MOTION IN THE ARMS OF THE SPIRAL NEBULA (M. 81)

STAR CLUSTER (M. 13) IN HERCULES

Probably we ought not to regard the two possibilities just mentioned as sharply cut alternatives. It is more likely that they represent the two extreme ends of a continuous chain of possible histories for the family of stars born out of a single nebula. It seems quite possible that what we describe as "the main mass of the stars" may be nothing more than a collection of clusters of stars, each cluster having originated out of a single nebula. The clusters are by now so intermingled that it is difficult to look on them as distinct groups of stars, although we can still find some evidence that this may be the proper way of regarding them. In 1905 Kapteyn showed that the stars in the neighborhood of the sun formed what he described as two "star streams," each stream moving with its own velocity in space. Except that it begs the question as to the extent of these streams in space, it would have been equally accurate to describe them as forming two intermingled moving clusters. Shortly after, Eddington and Halm, independently, found a third stream or moving cluster, constituted of the very hot stars which the astronomer classifies as stars of types B and O. In this case we know the extent of the cluster in space and also its approximate shape. According to Charlier, it is shaped like a round biscuit lying parallel to the Milky Way, its diameter being about 2.8 times its thickness. Any cluster of stars having a common origin, whatever shape it may assume at first, will be rapidly knocked out of shape when it begins to intermingle with other stars. Dynamical theory shows that after it has been knocked about ad infinitum in our universe of stars, such a cluster ought to assume the shape of a round biscuit parallel to the Milky Way, the ratio of its diameter to its thickness being about 2.5. This agrees sufficiently well with what is observed to suggest that all the stars in this stream have a common origin, and the same is true of many of the smaller known moving clusters, such as the Ursa Major cluster already mentioned. Thus, although we can not claim that anything is definitely proved, there is every justification for thinking of the main mass of the stars as a jumble of intermingled moving clusters, each cluster owing its existence to a separate nebula. This possibility has no very direct bearing on the question of the origin of our solar system; it has been mentioned merely as rounding off our knowledge of what appears to be the main evolutionary process of the stars.

In all its essentials except one, this evolutionary process is similar to, and in its earlier stages almost identical with, that which Laplace, in his famous nebular hypothesis, imagined as the origin of the solar system. We have seen before our eyes the rotating and shrinking nebula finally shedding matter from its equator; we have watched the condensation of this matter into separate masses, and

have finally witnessed the start of these detached masses on their voyages into space, all precisely as pictured by Laplace.

The one essential difference is that of size. The evolutionary process we have been watching occurs on a scale such as Laplace never dreamed of. His primeval nebula was supposed to be of about the size of Neptune's orbit, a size represented on the scale I used at the beginning of this lecture by a threepenny-bit. On this same scale the nucleus alone of a good-sized spiral nebula, such as those shown in Plate 3, Figure 2, and Plate 4, Figure 1, would be about the size of the Albert Hall, while the arms would sprawl over the whole of Hyde Park and Kensington. The pictures of these nebulæ that you have before you would have to be enlarged to the size of a whole country, or even possibly of a whole continent, before a body the size of our earth became visible in them at all.

Although the parent nebulæ we have been considering are all incomparably greater than Laplace's imaginary nebula, yet each tiny condensation, as it starts off into space, is a gaseous nebula the mass of which is just about equal to that imagined by Laplace and the size of which is not perhaps very greatly different. If, then, this younger generation of nebulæ meet with the same experiences in life as their giant parents before them, we should not have to look far for an explanation of the origin of the planets, and if the third generation again repeated the experience of their ancestors, the satellites of the planets are also accounted for. But mathematical research and observation agree in disposing of so simple an explanation of the origin of the solar system. As we have seen, it is only because the filaments in the spiral nebulæ are of such huge size that gravitation is able to cause condensation in opposition to the expansive tendency of gas pressure. A nebula of mass comparable to our sun might go through the same life history as the bigger nebula until matter began to be thrown off from its equator, but after this the difference of scale would begin to tell, and the subsequent course of events would be widely different. The ejected matter could not condense into filaments, still less into detached globules; it would merely constitute a diffuse atmosphere surrounding the parent nebula. As such a system shrank by the emission of radiation, the constancy of angular momentum would, at first, merely demand that more and more gas should be transferred from the center to the atmosphere.

But mathematical investigation shows that in time, after the central star had shrunk to a certain critical density, perhaps somewhere about one-tenth of that of water, a cataclysmic period would ensue, from which the mass would emerge as a binary star—two stars of comparable masses revolving about one another nearly in contact and in approximately circular orbits. This is a formation with

which the practical astronomer is very familiar. He finds that a very large proportion—perhaps about one-half—of the stars in the sky are binary, and he can detect an evolutionary sequence in these binary stars. The sequence starts with the formation just described in which the two constituent stars are almost in contact. As it progresses the stars move ever farther and farther apart, while the eccentricity of their orbits increases. Theory indicates that the process of fission which has broken up the original star into two constituents may repeat itself in either or both of these constituents, so that the final product may be a "multiple" star of either three or four constituents. Prof. H. N. Russell, investigating this question theoretically, found that certain numerical relations must hold between the relative distances of the various constituents of a multiple star; he also showed that the predictions of theory are confirmed quantitatively by observation.

So far, then, theory and observation have gone hand in hand. We have traced the evolution of astronomical matter through stages of ever-increasing density, from the most tenuous of nebulæ to the densest of multiple stars, and at almost every stage observation has confirmed the predictions of theory. Not all astronomical matter will traverse the whole length of this evolutionary course. The driving force on this course is increase of rotation consequent on the shrinkage produced by emission of radiation. When the shrinkage has proceeded a certain length solidification sets in; the rotation can increase now no further, and evolution, in the physical sense, stops. The distance along the course to which any particular system proceeds depends in effect on the amount of rotation with which it was originally endowed. Let a nebula begin its career with absolutely no rotation and it will remain sperical in shape throughout its whole career, ending merely as a cold non-radiating, but always spherical, mass. Such a nebula never even gets away from the starting-post. It is true that this is not a likely event, but for aught we know many a nebula may freeze and die before reaching the critical configuration (pl. 1, fig. 1) at which the birth of stars first commences. Similarly many of the stars may become cold and so cease to develop without ever attaining the stage at which binary systems are formed. In the same way many binary systems must fail to develop into multiple systems. Here again observation is with us; there are ten times as many purely binary systems known as there are multiple systems which have proceeded beyond the binary stage. Theory has traced out for us the whole length of the evolutionary course, but theory and observation agree that not many systems stay out the whole course.

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We now come to the crux of the whole question. Nowhere on this course have we found our solar system or anything in the least degree resembling it. If our sun had been unattended by planets we should have had no difficulty in guessing its origin. It might reasonably be supposed to have been born out of a nebula in the normal way, but to have emerged with insufficient rotation to have carried it on to the later stages of fission into a binary or a multiple system. It might, in fact, be supposed to have had the same evolutionary career as half of the stars in the sky. In support of the conjecture that our sun had been born out of a nebula in the ordinary way, we could note that its mass is about equal to what we calculate ought to be the mass of a star born out of a nebula, and that it is, apart from its planets, similar in every way to millions of other stars to which we may ascribe a nebular origin. In support of the conjecture that it had stopped short on its evolutionary course from want of adequate rotation to carry it on further, we should merely have to note the slowness of its present rotation. A simple calculation shows that the sun has only a small fraction of the amount of angular momentum requisite for fission. Even if we add the angular momentum of all the planets, as we ought if we suppose that these at one time formed part of the sun, the result is the same—the whole system can never have had more than a fraction of the angular momentum necessary for a rotational break-up into a binary star.

Thus the sun is a quite intelligible structure. The difficulty of our problem is not the origin of the sun but the origin of the planets and of their satellites.

Certain special types of astronomical structure have already been mentioned as not falling into place on the main line of evolutionary development. The particular examples chosen were the planetary nebulæ, the Cepheid variables, and the long-period variables. The question now arises as to whether we must add the solar system to the list. The circumstance that certain structures do not find a place in the evolutionary main line suggests that off this main line may be branch lines on to which the development of a system may in certain circumstances be turned. This, indeed, is only what might be anticipated. We should no more expect two stars to have precisely the same experiences in their careers than we should expect it of two humans. Our normal star has been supposed to develop in a universe of its own, where its angular momentum remained constant and where it was in every way unmolested by its neighbors. The mathematician finds it convenient to allot a whole infinite universe to each star, but nature does not. Nevertheless, the conditions postulated by the mathematician are nearer to the truth than is often the case in his idealized problems. On the scale we have already used, on which the sun was represented by a microscopic particle $\frac{1}{10000}$ inch

in diameter, the most gigantic of known giant stars may be represented by a pin head one-thirtieth of an inch in diameter. The present spacing of the stars is such that on this scale there is less than one star to a volume equal to the interior of St. Paul's Cathedral. Space then can not be said to be overcrowded, and although it is possible that the stars may disturb one another as they move in their courses, it is clear that any serious disturbance of one star by another must be a rather exceptional event. Obviously we have been right in regarding the evolution of a star entirely undisturbed by its neighbors as the normal course of evolution, and we can now see why the vast majority of stars follow this normal course.

To all appearances, the stars which have been sidetracked off this normal course are extraordinarily few in number. The total number of stars in the sky is about equal to the total population of the earth; the number of known exceptional systems would at most populate one small town, although, of course, we can scarcely even conjecture how many exceptional systems there may be which are still unknown to us. There is no reason for supposing that the sidetracking influence has in every case been a neighboring star, but the systems known to be exceptional are sufficiently few to suggest that this may have been the cause in a large proportion of cases.

The immediate question before us, however, is not that of the exceptional systems in general, but of our own solar system. Was it a neighboring star that threw it off the main line of evolutionary development? Here, for the first time, observational astronomy denies us any help. Not a single system is known outside our solar system which resembles it in the least degree. The reason is not that no such system exists, but that we could not see it if it did. An astronomer on a distant star observing our system would see Jupiter as the brightest object after our sun, but the ratio of their luminosities would be as 300,000,000 to 1. Seen from our nearest known neighbor in space, Proxima Centauri, the sun would appear as a first magnitude star, and Jupiter as a star of magnitude 22.2, the distance between them being at most four seconds of arc. A star of magnitude 22.2 is still well beyond the range of our largest telescopes, and would be doubly invisible if it had a first magnitude star only four seconds away. We must wait for a very great increase in the power of our telescopes before there will be any hope of seeing systems similar to our own in the sky, even if they exist no further away from us than Proxima Centauri. Thus it is clear that our discussion has now left the regions in which observation can be called upon to make suggestions or to check our conclusions: henceforth we have theory alone to guide us.

Let us start on our quest by noticing that our solar system has quite clearly marked characteristics. It is no mere jumble of bodies

looking as though they had fallen together by accident—had it presented this appearance the problem of its origin might reasonably be dismissed as hopeless. Not only has the principal system of the sun and its planets got clearly marked characteristics, but also these same characteristics reappear in the smaller systems formed by Jupiter and Saturn, each with its family of satellites. Each of these small systems is, to all intents and purposes, a replica in miniature of the solar system, so much so that no suggested origin for one system can be regarded as satisfactory unless at the same time it explains the origin of the other two. The principal features common to the three systems are, that the orbits in all three systems are with few exceptions, all in or close to one plane, that these orbits are all described in the same direction, and that the masses of the secondaries, whether planets or satellites, are all small in comparison with those of the primaries around which they revolve. Thus the sun has a mass equal to 1,047 times that of his greatest planet, Jupiter, while Jupiter's mass is about 11,000 times that of his most massive satellite. The smallest disparity in mass is found in our own Earth-Moon system with a mass ratio of 81 to 1. In systems possessing many satellites (those of the Sun, Jupiter, and Saturn) there is a general tendency for the masses to increase up to a maximum as we pass outward through the system, and then to decrease to a minimum. Thus in the main system there is a regular progression through Mercury, Venus, Earth, Mars to the maximum mass of Jupiter, broken only by the anomalous position of Mars, while on the descending side the progression through Jupiter, Saturn, Uranus, Neptune fails in regularity only through Neptune being some few per cent more massive than Uranus.

The main line of evolutionary progress has been supposed to be that of a mass of shrinking, rotating matter—first gaseous, then liquid, then solid—left to itself in space. Such a system must show one very marked characteristic throughout its whole career, namely, a plane of symmetry. In its earliest stage of all, when the system is a mere chaos of independent molecules, the plane will coincide with what mathematicians describe as the "invariable plane" of the system. Later, when the mass has assumed the regular shape of a rotating nebula, the plane is the equatorial plane of the nebula, the plane in which the arms subsequently appear and in which the stellar condensations start off in their orbits. The symmetry of spiral nebulæ about their equatorial planes would of itself suggest strongly that they have developed to their present formations as rotating bodies practically undisturbed by external influences.

If our solar system had developed out of an undisturbed rotating mass, it, too, ought to exhibit a plane of symmetry. The orbits of nearly all the planets and their satellites do, in actual fact, lie

very nearly in one plane, which, to this extent, is, of course, a plane of symmetry. But the sun's axis of rotation is not perpendicular to this plane; the sun has its own plane of symmetry in its equator, and this is inclined at an angle of 7° to the plane of orbits.

The existence of these two distinct planes is enough in itself to suggest that our system has not developed simply out of an undisturbed rotating mass. Thus, in tracing our system back to its origin, we naturally look at the effects to be expected from rotation plus some external influence. To a first rough approximation, it is natural to suppose that the plane of the sun's equator records the plane of rotation of the original system, while the plane of the planetary orbits was in some way determined by the extraneous disturbance.

Of all the interactions between two separate astronomical bodies, gravitational attraction is likely to be by far the most potent. The moon has been accused of exerting all kinds of influences on our earth, as, for example, on its weather, on the destinies, the emotions, and even on the sanity of its inhabitants; but the only influence which survives scientific examination is gravitational attraction as evidenced by the semidiurnal tides. It is true that a head-on collision between two astronomical bodies would produce more immediately dramatic results than a mere tidal pull; but we shall not consider such an event here. Head-on collisions must of necessity be exceedingly rare; systems that experience them would undoubtedly be deflected from the main line of evolutionary progress on to a branch line; but it does not seem likely that this branch line contains systems like our own. As time does not permit the exploration of all conceivable branch lines, let us turn at once to that which seems most likely to reveal the origin of our system—the branch line that diverges from the main line at the occurrence of a violent tidal encounter.

On the earth, our moon raises tides the average height of which at high tide is only a few feet. This height of high tide is only about a ten-millionth part of the earth's radius, a fraction which we may designate as the tidal fraction. If the moon were ten times as massive, the tidal fraction would be increased tenfold; if it were brought to half its present distance, the tidal fraction would be increased eightfold. If we agree to measure masses in terms of the body on which the tide is raised as unity and to measure lengths in terms of the radius of the same body, then the tidal fraction is equal to the mass of the tide-generating body divided by the cube of its distance, say M/R^3. Using this formula, we find that our nearest neighbor, Proxima Centauri, raises on the sun a tide of quite infinitesimal magnitude; the tidal fraction is about 10^{-26}, and the actual height of tide is of the order of 10^{-15} cm., or, say, one-

fiftieth of the radius of an electron. This single illustration will show, and with some margin to spare, that under normal conditions the tidal influence between neighboring stars is utterly insignificant. For tidal forces to become important to cosmogony, conditions must be abnormal.

Our sun happens at the present moment to have no especially near neighbor; but it is fairly certain that at some time, in its wanderings through the stars, it must have passed stars within a much less distance than that which now separates it from Proxima Centauri. The most trustworthy lines of evidence as to the earth's age, namely, those from geology and radioactivity, indicate an age of from 800 to 1,100 million years. For precision, let us think of the sun's age as 1,000 million years. Let us imagine for the moment, what is no doubt very far from the truth, that throughout all this thousand million years the sun and all the stars have moved just as they are moving now, with the same average velocities as now, and keeping at the same average distance apart. Throughout this thousand million years the distance of our sun from its nearest neighbor will have been continually changing, and one star after another will, of course, have taken up the rôle of nearest neighbor. But there must have been some one instant in this thousand million years at which our sun was nearer than at any other instant to its nearest neighbor. A calculation based on the theory of probability indicates that this nearest distance is likely to have been of the order of 7×10^{15} cm., a distance which, although only a six-hundredth of that which now separates us from Proxima Centauri, is still equal to fifteen times the radius of Neptune's orbit. Even if the sun had filled the whole of Neptune's orbit, the tidal fraction at this closest encounter, on the supposition that the nearest star had a mass equal to the sun, would only be equal to $1/(15)^3$ or 1/3375, giving a height of tide which is quite unimportant from the point of view of cosmogony. So long as things have been as they now are, tidal actions between separate stars must have been quite devoid of cosmogonic interest, except possibly in very special cases of quite exceptionally close approaches.

It is, of course, possible that our sun was the victim of one of those exceptionally close encounters. Nothing can be brought against the supposition of such an event, except its a priori improbability. The result of such a close encounter might, as we shall see, be the creation of a system in many ways resembling our solar system.

Our calculations of probabilities and improbabilities have, however, rested upon the admittedly erroneous assumption that stellar conditions have been similar to the present ones for a period of a thousand million years. On looking back through the past history of the universe, we come to a time when conditions must have been

very different from what they are now. We come to a time, which we have already considered, when our sun had not yet assumed its present stellar characteristics. It was a condensation in the arm of a spiral nebula moving with thousands of similar condensations towards a free career in space. Its density was enormously lower than it now is, and its size correspondingly greater. It was also much nearer to its neighbors than, in all probability, it has ever been since. In this early stage of its existence, the tidal effects of its neighbors may well have been enormous; we shall pass to exact figures in a moment.

In general, the passage of one star past another merely raises a tide which subsides as the tide-raising body recedes. Even when the approach is so close that the height of the tide raised is greater than the original radius of the star, the recession of the disturbing star may result in the disturbed star relapsing merely to its original spherical form. But there is a limit which must not be passed, and if the disturbing body passes this limit, all hope of the star resuming its original shape is lost. The distance of the limit depends primarily on the mass of the disturber: to a lesser degree it depends on the rotation, shape, and density-distribution of the primary star; and to some extent it depends on the velocity of the two stars relative to one another. We shall get a tolerable idea of the march of events if we suppose the primary star to be surrounded by an imaginary sphere the radius of which depends solely on the mass of the disturbing star. If this mass is equal to the mass of the primary, the radius of this imaginary sphere will be about 2¼ times the radius of the primary; if the disturbing star has 8 times the mass of the primary, the radius of the imaginary sphere will be 4½ times that of the primary, and so on. So long as the center of the visiting star remains outside the sphere, a tide is raised which recedes as the visiting star disappears, but the moment the visiting star invades this sphere an entirely new phenomenon appears.

As the approach of the disturber raises the tide to higher and higher levels, the highest points of the tide move ever farther away from the star's center into regions where the gravitational attraction of the star gets weaker and weaker. At the same time, of course, the gravitational pull of the visiting star gets stronger and stronger. Finally, just as the visiting star crosses the critical sphere, its gravitational pull just balances that of the primary—it is this condition that defines the critical sphere. If the visiting star further invades this critical sphere, the particles at high tide are shot away from the primary star, the resultant gravitational force on them now being definitely toward the visiting star; they are, of course, immediately replaced by others, which are shot off in turn, and so on. The total effect is that a filament or jet of gas is shot out from the point of

high tide. Each particle of this jet moves under the combined forces of the primary and of the visiting star, and the problem of determining its orbit is a special case of the problem of three bodies, which unfortunately is not soluble. But the general result is that the jet undergoes various contortions while moving all the time in the plane which contains the orbit of the visiting star.

If such a jet had been thrown off the sun simply by an increase of rotation consequent on shrinkage, its gravitational attraction would, as we have seen, be inadequate to resist the expansive effect of its own gas pressure, and it would have been rapidly dissipated away into space. In the present situation conditions are very different, the essential difference being that, while shrinkage from loss of radiation is a very slow process, tidal disruption may be a very rapid process. The rate of a star's rotation will alter but slightly in a thousand years, whereas 10 years may suffice for a tide-raising body to come, do its work, and go away again. The filament of gas set free by increase of rotation would be of extreme tenuity; a filament set free by a tidal cataclysm might easily be of sufficient substance for its own gravitation to hold it together as a compact whole.

If gravitation is potent enough to do this, it will also be potent enough to break up the filament into condensations, just as the filaments of spiral nebulæ are broken up into condensations. But here again an essential difference must be taken into account. The shrinkage of a spiral nebula is a slow secular process. Year after year and century after century the filament will be ejected without change of character—the process may be compared to the paying out of a coil of rope. But the tidal disruption of a star is a rapid, even cataclysmic event; within a few years the emission of the filament starts, reaches a maximum, declines, and ends. There is no steady paying out here; the process ought rather to be compared to the discharge of a torpedo, or other body which is thickest in the middle and tapers off at the two ends. When a filament of this shape breaks up into condensations it will form no long chain of similar masses, but a small number of unequal masses. It is natural to conjecture a priori that large masses are likely to form out of the central portions where matter is most plentiful, and smaller masses at the ends where matter is scarce. Such a question can not, of course, be finally settled by a priori conjectures, but in the present case an exact discussion of the problem indicates that the a priori view is the right one, and suggests that the comparative abundance of matter in the central part of the filament may provide an explanation of the appearance of the more massive planets, Jupiter and Saturn, near the center of the sequence of planets.

Obviously, if a tidal cataclysm can explain the existence of the planets, it can also, in general terms at least, explain the existence of

the satellites of these planets. For immediately after the birth of any planet, say Jupiter, the original situation repeats itself in miniature. Jupiter now plays the part originally assigned to the sun, while either the wandering star or the sun itself, or possibly the combination of the two, acts the part of the tide-raising disturber. Again we get the emitted filament, again the formation of condensations, and again, as the ultimate result, a sequence of detached bodies with the most massive in the middle. Since Jupiter, the sun, and the disturbing star all move in the same plane—namely, the plane of Jupiter's orbit—it follows that Jupiter's satellites, when formed, ought also to move in this plane, as in actual fact they are observed to do.

So long as we merely discuss the matter in general terms it looks as though the process might go on for generation after generation, each member of a family of satellites producing minor satellites to circle round itself, and so on ad infinitum. Common sense suggests that this can not go on forever; there must be a limit somewhere. Exact calculation confirms the view of common-sense, with the disconcerting addition, that we are in danger of overstepping the limit if we attempt to account for the whole of the satellites in the solar system in the way just suggested.

I have already mentioned a mathematical formula which enables us to calculate the masses of the bodies formed out of the condensations in the arms of spiral nebulæ. The same formula puts us in a position to calculate the masses of the planets which ought to be formed from the filament drawn out of the sun. Let us suppose that when the tidal cataclysm took place the sun had a radius equal to that of Neptune's orbit, and therefore a mean density of 5.5×10^{-12}. Let us suppose that at the middle parts of the ejected filament the mean density was one-tenth of this, or 5.5×10^{-13}. Let us further suppose that the temperature of the ejected matter corresponded to a molecular velocity 4×10^{4}, this being about the molecular velocity of hydrogen or oxygen at their ordinary boiling points. Then our formula indicates that the masses of the planets formed out of the middle parts of the filament ought to be about 10^{30} gm., a mass intermediate between those of Jupiter and Saturn. This is satisfactory as showing that there is no numerical difficulty in supposing Jupiter and Saturn to have come into being in the way we have imagined. If we like to accept the tidal theory of their birth, we can reverse our calculation and can calculate from their present known masses what must have been the density of the matter from which they were formed.

Naturally an inverted calculation of this kind is not applicable only to Jupiter and Saturn; if the tidal hypothesis is correct it must be applicable to all the planets and to all their satellites. For example, the first five satellites of Saturn all have masses of about

5×10^{23} gm.; our calculation shows that if these satellites came into being as gaseous condensations in a filament, the gas in this filament must have been anything from one to a million times as dense as lead. Such a conclusion is, of course, preposterous. The only proper conclusion is that these satellites can not have originated as gaseous condensations.

This conclusion is not surprising, or even unexpected. Even now these satellites, on account of the smallness of their mass, are incapable of retaining a gaseous atmosphere, whence it follows that they can never have existed in the gaseous state. They must have been born either liquid or solid.

In this way we come upon the practical limitation to the possibility of endless generations of satellites being born. Primarily it is that after a time the satellites would be too small for their gravitation to hold them together. A brief reprieve from the operation of this law is afforded by the possibility of the matter liquefying or even solidifying before it scatters into space, and it is probably owing to the operation of this reprieve that all the satellites of the planets, and probably also the smaller planets themselves, owe their existence.

What of our earth, which interests us above all other planets? Its present mass is rather too small to have been born out of a purely gaseous filament, but we must remember that if it were born gaseous a large part of its mass might be immediately dissipated away into space, the present earth representing only a remnant of a once much more massive planet. This line of investigation leads nowhere. A more promising line of attack is through a consideration of our satellite, the moon. The more liquid a planet was at its birth the less likely was it to be broken up tidally by the still gaseous sun, but, in the event of this breaking up taking place, the ratio of mass between satellite and primary would be much nearer to unity than in the case of a wholly gaseous planet. Thus, as we pass from planets which were wholly gaseous at birth to planets which were wholly liquid, we ought to start from planets with large numbers of relatively small satellites, and after passing through the boundary cases of planets with a small number of relatively large satellites reach planets having no satellites at all. This is precisely what we find in the solar system. Leaving Jupiter and Saturn, each with their nine relatively small satellites, we pass through Mars, with its two satellites, to the earth, with one relatively very large satellite, and after this come to Venus and Mercury, with no satellites at all. Proceeding in the other direction from Jupiter and Saturn, we pass through Uranus, with four small satellites, to Neptune, with one comparatively big satellite. Looked at from this point of view, the earth-moon system figures as the obvious boundary case between the planets which were

originally liquid and those which were originally gaseous, the corresponding boundary case on the other half of the chain being Neptune. Thus we can conjecture that Mercury and Venus were born liquid or solid, that the earth and Neptune were born partly liquid and partly gaseous, and that Mars, Jupiter, Saturn, and Uranus were born gaseous.

We have already noticed that Mars and Uranus both have masses which are too small for their positions in the sequence of planets. If the planets were born out of a filament of continuously varying density, the mass of Mars at birth ought to have been intermediate between that of the earth and that of Jupiter, and similarly the mass of Uranus at birth ought to have been intermediate between that of Neptune and that of Saturn. We have, however, just seen reasons for conjecturing that the two anomalous planets, Mars and Uranus, were the two smallest planets to be born in the gaseous state; they would, therefore, be likely to lose more mass by dissipation of their outer layers than any of the other planets. Let us introduce the supposition that Mars, and to a lesser degree Uranus, lost large parts of their mass by dissipation into space; let us suppose that they are mere fragments of what were originally much more massive planets, then all anomalies disappear, and the pieces of the puzzle begin to fit together in a very gratifying manner.

Nevertheless, and in spite of the high promise which the tidal theory seems to hold out, it is far too early to claim that it can finally explain the origin of our system. Its claim to consideration at present is rather that, so far as I know, it provides the only theory of that origin which is not open to obvious and insuperable objections.

THE ELECTRICAL STRUCTURE OF MATTER[1]

By Prof. Sir Ernest Rutherford, D. Sc., LL. D., Ph. D., F. R. S.

It was in 1896 that this association last met in Liverpool, under the presidency of the late Lord Lister, that great pioneer in antiseptic surgery, whose memory is held in affectionate remembrance by all nations. His address, which dealt mainly with the history of the application of antiseptic methods to surgery and its connection with the work of Pasteur, that prince of experimenters, whose birth has been so fittingly celebrated this year, gave us in a sense a completed page of brilliant scientific history. At the same time, in his opening remarks, Lister emphasized the importance of the discovery by Röntgen of a new type of radiation, the X rays, which we now see marked the beginning of a new and fruitful era in another branch of the science.

The visit to your city in 1896 was for me a memorable occasion, for it was here that I first attended a meeting of this association, and hear that I read my first scientific paper. But of much more importance, it was here that I benefited by the opportunity, which these gatherings so amply afford, of meeting for the first time many of the distinguished scientific men of this country and the foreign representatives of science who were the guests of this city on that occasion. The year 1896 has always seemed to me a memorable one for other reasons, for on looking back with some sense of perspective we can not fail to recognize that the last Liverpool meeting marked the beginning of what has been aptly termed the heroic age of physical science. Never before in the history of physics has there been witnessed such a period of intense activity when discoveries of fundamental importance have followed one another with such bewildering rapidity.

The discovery of X rays by Röntgen had been published to the world in 1895, while the discovery of the radioactivity of uranium by Becquerel was announced early in 1896. Even the most imaginative of our scientific men could never have dreamed at that time of the extension of our knowledge of the structure of matter that was to

[1] Presidential address before the British Association for the Advancement of Science, Liverpool. 1923. Reprinted by permission from the Proceedings of the Association, 1923.

develop from these two fundamental discoveries, but in the records of the Liverpool meeting we see the dawning recognition of the possible consequences of the discovery of X rays, not only in their application to medicine and surgery, but as a new and powerful agent for attacking some of the fundamental problems of physics. The address of Prof. J. J. Thomson, president of Section A, was devoted mainly to a discussion of the nature of the X rays, and the remarkable properties induced in gases by the passage of X rays through them—the beginning of a new and fruitful branch of study.

In applied physics, too, this year marked the beginning of another advance. In the discussion of a paper which I had the honor to read, on a new magnetic detector of electrical waves, the late Sir William Preece told the meeting of the successful transmission of signals for a few hundred yards by electrical waves which had been made in England by a young Italian, G. Marconi. The first public demonstration of signaling for short distances by electric waves had been given by Sir Oliver Lodge at the Oxford meeting of this association in 1894. It is startling to recall the rapidity of the development from such small beginnings of the new method of wireless intercommunication over the greatest terrestrial distances. In the last few years this has been followed by the even more rapid growth of the allied subject of radiotelephony as a practical means of broadcasting speech and music to distances only limited by the power of the transmitting station. The rapidity of these technical advances is an illustration of the close interconnection that must exist between pure and applied science if rapid and sure progress is to be made. The electrical engineer has been able to base his technical developments on the solid foundation of Maxwell's electromagnetic theory and its complete verification by the researches of Hertz, and also by the experiments of Sir Oliver Lodge in this university—a verification which was completed long before the practical possibilities of this new method of signaling had been generally recognized. The later advances in radiotelegraphy and radiotelephony have largely depended on the application of the results of fundamental researches on the properties of electrons, as illustrated in the use of the thermionic valve or electron tube which has proved such an invaluable agent both for the transmission and reception of electric waves.

It is of great interest to note that the benefits of this union of pure and applied research have not been one-sided. If the fundamental researches of the workers in pure science supply the foundations on which the applications are surely built, the successful practical application in turn quickens and extends the interest of the investigator in the fundamental problem, while the development of new methods and appliances required for technical purposes often pro-

vides the investigator with means of attacking still more difficult questions. This important reaction between pure and applied science can be illustrated in many branches of knowledge. It is particularly manifest in the industrial development of X-ray radiography for therapeutic and industrial purposes, where the development on a large scale of special X-ray tubes and improved methods of excitation has given the physicist much more efficient tools to carry out his researches on the nature of the rays themselves and on the structure of the atom. In this age no one can draw any sharp line of distinction between the importance of so-called pure and applied research. Both are equally essential to progress, and we can not but recognize that without flourishing schools of research on fundamental matters in our universities and scientific institutions technical research must tend to wither. Fortunately there is little need to labor this point at the moment, for the importance of a training in pure research has been generally recognized. The Department of Scientific and Industrial Research has made a generous provision of grants to train qualified young men of promise in research methods in our scientific institutions, and has aided special fundamental researches which are clearly beyond the capacity of a laboratory to finance from its own funds. Those who have the responsibility of administering the grants in aid of research, both for pure and applied science, will need all their wisdom and experience to make a wise allocation of funds to secure the maximum of results for the minimum of expenditure. It is fatally easy to spend much money in direct frontal attack on some technical problem of importance when the solution may depend on some addition to knowledge which can be gained in some other field of scientific inquiry possibly at a trifling cost. It is not in any sense my purpose to criticize those bodies which administer funds for fostering pure and applied research, but to emphasize how difficult it is to strike the correct balance between the expenditure on pure and applied science in order to achieve the best results in the long run.

It is my intention this evening to refer very briefly to some of the main features of that great advance in knowledge of the nature of electricity and matter which is one of the salient features of the interval since the last meeting of this association in Liverpool.

In order to view the extensive territory which has been conquered by science in this interval, it is desirable to give a brief summary of the state of knowledge of the constitution of matter at the beginning of this epoch. Ever since its announcement by Dalton the atomic theory has steadily gained ground, and formed the philosophic basis for the explanation of the facts of chemical combination. In the early stages of its application to physics and chemistry it was unnecessary to have any detailed knowledge of the di-

mensions or structure of the atom. It was only necessary to assume that the atoms acted as individual units, and to know the relative masses of the atoms of the different elements. In the next stage, for example, in the kinetic theory of gases, it was possible to explain the main properties of gases by supposing that the atoms of the gas acted as minute perfectly elastic spheres. During this period, by the application of a variety of methods, many of which were due to Lord Kelvin, rough estimates had been obtained of the absolute dimensions and mass of the atoms. These brought out the minute size and mass of the atom and the enormous number of atoms necessary to produce a detectable effect in any kind of measurement. From this arose the general idea that the atomic theory must of necessity forever remain unverifiable by direct experiment, and for this reason it was suggested by one school of thought that the atomic theory should be banished from the teaching of chemistry, and that the law of multiple proportions should be accepted as the ultimate fact of chemistry.

While the vaguest ideas were held as to the possible structure of atoms, there was a general belief among the more philosophically minded that the atoms of the elements could not be regarded as simple unconnected units. The periodic variations of the properties of the elements brought out by Mendeleeff were only explicable if atoms were similar structures in some way constructed of similar material. We shall see that the problem of the constitution of atoms is intimately connected with our conception of the nature of electricity. The wonderful success of the electromagnetic theory had concentrated attention on the medium or ether surrounding the conductor of electricity, and little attention had been paid to the actual carriers of the electric current itself. At the same time the idea was generally gaining ground that an explanation of the results of Faraday's experiments on electrolysis was only possible on the assumption that electricity, like matter, was atomic in nature.

The name "electron" had even been given to this fundamental unit by Johnstone Stoney, and its magnitude roughly estimated, but the full recognition of the significance and importance of this conception belongs to the new epoch.

For the clarifying of these somewhat vague ideas, the proof in 1897 of the independent existence of the electron as a mobile electrified unit, of mass minute compared with that of the lightest atom, was of extraordinary importance. It was soon seen that the electron must be a constituent of all the atoms of matter, and that optical spectra had their origin in their vibrations. The discovery of the electron and the proof of its liberation by a variety of methods from all the atoms of matter was of the utmost significance, for it strengthened the view that the electron was probably

the common unit in the structure of atoms which the periodic variation of the chemical properties had indicated. It gave for the first time some hope of the success of an attack on that most fundamental of all problems—the detailed structure of the atom. In the early development of this subject science owes much to the work of Sir J. J. Thomson, both for the boldness of his ideas and for his ingenuity in developing methods for estimating the number of electrons in the atom, and of probing its structure. He early took the view that the atom must be an electrical structure, held together by electrical forces, and showed in a general way lines of possible explanation of the variation of physical and chemical properties of the elements, exemplified in the periodic law.

In the meantime our whole conception of the atom and of the magnitude of the forces which held it together was revolutionized by the study of radioactivity. The discovery of radium was a great step in advance, for it provided the experimenter with powerful sources of radiation specially suitable for examining the nature of the characteristic radiations which are emitted by the radioactive bodies in general. It was soon shown that the atoms of radioactive matter were undergoing spontaneous transformation, and that the characteristic radiations emitted, viz, the α, β, and γ rays, were an accompaniment and consequence of these atomic explosions. The wonderful succession of changes that occur in uranium, more than 30 in number, was soon disclosed and simply interpreted on the transformation theory. The radioactive elements provide us for the first time with a glimpse into Nature's laboratory and allow us to watch and study but not control the changes that have their origin in the heart of the radioactive atoms. These atomic explosions involve energies which are gigantic compared with those involved in any ordinary physical or chemical process. In the majority of cases an α particle is expelled at high speed, but in others a swift electron is ejected often accompanied by a γ ray, which is a very penetrating X ray of high frequency. The proof that the α particle is a charged helium atom for the first time disclosed the importance of helium as one of the units in the structure of the radioactive atoms, and probably also in that of the atoms of most of the ordinary elements. Not only then have the radioactive elements had the greatest direct influence on natural philosophy, but in subsidiary ways they have provided us with experimental methods of almost equal importance. The use of α particles as projectiles with which to explore the interior of the atom has definitely exhibited its nuclear structure, has led to artificial disintegration of certain light atoms, and promises to yield more information yet as to the actual structure of the nucleus itself.

The influence of radioactivity has also extended to yet another field of study of fascinating interest. We have seen that the first rough estimates of the size and mass of the atom gave little hope that we could detect the effect of a single atom. The discovery that the radioactive bodies expel actual charged atoms of helium with enormous energy altered this aspect of the problem. The energy associated with a single α particle is so great that it can readily be detected by a variety of methods. Each α particle, as Sir William Crookes first showed, produces a flash of light easily visible in a dark room when it falls on a screen coated with crystals of zinc sulphide. This scintillation method of counting individual particles has proved invaluable in many researches, for it gives us a method of unequaled delicacy for studying the effects of single atoms. The α particle can also be detected electrically or photographically, but the most powerful and beautiful of all methods is that perfected by Mr. C. T. R. Wilson for observing the track through a gas not only of an α particle but of any type of penetrating radiation which produces ions or of electrified particles along its path. The method is comparatively simple, depending on the fact, first discovered by him, that if a gas saturated with moisture is suddenly cooled each of the ions produced by the radiation becomes the nucleus of a visible drop of water. The waterdrops along the track of the α particle are clearly visible to the eye, and can be recorded photographically. These beautiful photographs of the effect produced by single atoms or single electrons appeal, I think, greatly to all scientific men. They not only afford convincing evidence of the discrete nature of these particles, but give us new courage and confidence that the scientific methods of experiment and deduction are to be relied upon in this field of inquiry; for many of the essential points brought out so clearly and concretely in these photographs were correctly deduced long before such confirmatory photographs were available. At the same time, a minute study of the detail disclosed in these photographs gives us most valuable information and new clues on many recondite effects produced by the passage through matter of these flying projectiles and penetrating radiations.

In the meantime a number of new methods had been devised to fix with some accuracy the mass of the individual atom and the number in any given quantity of matter. The concordant results obtained by widely different physical principles gave great confidence in the correctness of the atomic idea of matter. The method found capable of most accuracy depends on the definite proof of the atomic nature of electricity and the exact valuation of this fundamental unit of charge. We have seen that it was early surmised that electricity was atomic in nature. This view was confirmed and extended by a study

of the charges carried by electrons, α particles, and the ions produced in gases by X rays and the rays from radioactive matter. It was first shown by Townsend that the positive or negative charge carried by an ion in gases was invariably equal to the charge carried by the hydrogen ion in the electrolysis of water, which we have seen was assumed, and assumed correctly, by Johnstone Stoney to be the fundamental unit of charge. Various methods were devised to measure the magnitude of this fundamental unit; the best known and most accurate is that used by Millikan, which depends on comparing the pull of an electric field on a charged droplet of oil or mercury with the weight of the drop. His experiments gave a most convincing proof of the correctness of the electronic theory, and gave a measure of this unit, the most fundamental of all physical units, with an accuracy of about one in a thousand. Knowing this value, we can by the aid of electrochemical data easily deduce the mass of the individual atoms and the number of molecules in a cubic centimeter of any gas with an accuracy of possibly one in a thousand, but certainly better than one in a hundred. When we consider the minuteness of the unit of electricity and of the mass of the atom this experimental achievement is one of the most notable even in an era of great advances.

The idea of the atomic nature of electricity is very closely connected with the attack on the problem of the structure of the atom. If the atom is an electrical structure it can only contain an integral number of charged units, and, since it is ordinarily neutral, the number of units of positive charge must equal the number of negative. One of the main difficulties in this problem has been the uncertainty as to the relative part played by positive and negative electricity in the structure of the atom. We know that the electron has a negative charge of one fundamental unit, while the charged hydrogen atom, whether in electrolysis or in the electric discharge, has a charge of one positive unit. But the mass of the electron is only 1/1840 of the mass of the hydrogen atom, and though an extensive search has been made, not the slightest evidence has been found of the existence of a positive electron of small mass like the negative. In no case has a positive charge been found associated with a mass less than that of the charged atom of hydrogen. This difference between positive and negative electricity is at first sight very surprising, but the deeper we pursue our inquiries the more this fundamental difference between the units of positive and negative electricity is emphasized. In fact, as we shall see later, the atoms are quite unsymmetrical structures with regard to the positive and negative units contained in them, and indeed it seems certain that if there were not this difference in mass between the two units, matter, as we know it, could not exist.

It is natural to inquire what explanation can be given of this striking difference in mass of the two units. I think all scientific men are convinced that the small mass of the negative electron is to be entirely associated with the energy of its electrical structure, so that the electron may be regarded as a disembodied atom of negative electricity. We know that an electron in motion, in addition to possessing an electric field, also generates a magnetic field around it, and energy in the electromagnetic form is stored in the medium and moves with it. This gives the electron an apparent or electrical mass, which, while nearly constant for slow speeds, increases rapidly as its velocity approaches that of light. This increase of mass is in good accord with calculation, whether based on the ordinary electrical theory or on the theory of relativity. Now we know that the hydrogen atom is the lightest of all atoms, and is presumably the simplest in structure, and that the charged hydrogen atom, which we shall see is to be regarded as the hydrogen nucleus, carries a unit positive charge. It is thus natural to suppose that the hydrogen nucleus is the atom of positive electricity, or positive electron, analogous to the negative electron, but differing from it in mass. Electrical theory shows that the mass of a given charge of electricity increases with the concentration, and the greater mass of the hydrogen nucleus would be accounted for if its size were much smaller than that of the electron. Such a conclusion is supported by evidence obtained from the study of the close collisions of α particles with hydrogen nuclei. It is found that the hydrogen nucleus must be of minute size, of radius less than the electron, which is usually supposed to be about 10^{-13} cms.; also the experimental evidence is not inconsistent with the view that the hydrogen nucleus may actually be much smaller than the electron. While the greater mass of the positive atom of electricity may be explained in this way, we are still left with the enigma why the two units of electricity should differ so markedly in this respect. In the present state of our knowledge it does not seem possible to push this inquiry further or to discuss the problem of the relation of these two units.

We shall see that there is the strongest evidence that the atoms of matter are built up of these two electrical units, viz, the electron and the hydrogen nucleus or proton, as it is usually called when it forms part of the structure of any atom. It is probable that these two are the fundamental and indivisible units which build up our universe, but we may reserve in our mind the possibility that further inquiry may some day show that these units are complex, and divisible into even more fundamental entities. On the views we have outlined, the mass of the atom is the sum of the electrical masses of the individual charged units composing its structure, and there is no need to assume that any other kind of mass exists. At the same time, it is

to be borne in mind that the actual mass of an atom may be somewhat less than the sum of the masses of component positive and negative electrons when in the free state. On account of the very close proximity of the charged units in the nucleus of an atom, and the consequent disturbance of the electric and magnetic field surrounding them, such a decrease of mass is to be anticipated on general theoretical grounds.

We must now look back again to the earlier stages of the present epoch in order to trace the development of our ideas on the detailed structure of the atom. That electrons as such were important constituents was clear by 1900, but little real progress followed until the part played by the positive charges was made clear. New light was thrown on this subject by examining the deviation of α particles when they passed through the atoms of matter. It was found that occasionally a swift α particle was deflected from its rectilinear path through more than a right angle by an encounter with a single atom. In such a collision the laws of dynamics ordinarily apply, and the relation between the velocities of the colliding atoms before and after collision are exactly the same as if the two colliding particles are regarded as perfectly elastic spheres of minute dimensions. It must, however, be borne in mind that in these atomic collisions there is no question of mechanical impacts such as we observe with ordinary matter. The reaction between the two particles occurs through the intermediary of the powerful electric fields that surround them. Beautiful photographs illustrating the accuracy of these laws of collision between an α particle and an atom have been obtained by Messrs. Wilson, Blackett, and others, while Mr. Wilson has recently obtained many striking illustrations of collisions between two electrons. Remembering the great kinetic energy of the α particle, its deflection through a large angle in a single atomic encounter shows clearly that very intense deflecting forces exist inside the atom. It seemed clear that electric fields of the required magnitude could be obtained only if the main charge of the atom were concentrated in a minute nucleus. From this arose the conception of the nuclear atom, now so well known, in which the heart of the atom is supposed to consist of a minute but massive nucleus, carrying a positive charge of electricity, and surrounded at a distance by the requisite number of electrons to form a neutral atom.

A detailed study of the scattering of α particles at different angles by Geiger and Marsden showed that the results were in close accord with this theory, and that the intense forces near the nucleus varied according to the ordinary inverse square law. In addition, the experiments allowed us to fix an upper limit for the dimensions of the nucleus. For a heavy atom like that of gold the radius of the nucleus, if supposed to be spherical, was less than one thousandth

of the radius of the complete atom surrounded by its electrons, and certainly less than 4×10^{-12} cms. All the atoms were found to show this nuclear structure, and an approximate estimate was made of the nuclear charge of different atoms. This type of nuclear atom, based on direct experimental evidence, possesses some very simple properties. It is obvious that the number of units of resultant positive charge in the nucleus fixes the number of the outer planetary electrons in the neutral atom. In addition, since these outer electrons are in some way held in equilibrium by the attractive forces from the nucleus, and, since we are confident from general physical and chemical evidence that all atoms of any one element are identical in their external structure, it is clear that their arrangement and motion must be governed entirely by the magnitude of the nuclear charge. Since the ordinary chemical and physical properties are to be ascribed mainly to the configuration and motion of the outer electrons, it follows that the properties of an atom are defined by a whole number representing its nuclear charge. It thus becomes of great importance to determine the value of this nuclear charge for the atoms of all the elements.

Data obtained from the scattering of α particles, and also from the scattering of X rays by light elements, indicated that the nuclear charge of an element was numerically equal to about half the atomic weight in terms of hydrogen. It was fairly clear from general evidence that the hydrogen nucleus had a charge one, and the helium nucleus (the α particle) a charge two. At this stage another discovery of great importance provided a powerful method of attack on this problem. The investigation by Laue on the diffraction of X rays by crystals had shown definitely that X rays were electromagnetic waves of much shorter wave-length than light, and the experiments of Sir William Bragg and W. L. Bragg had provided simple methods for studying the spectra of a beam of X rays. It was found that the spectrum in general shows a continuous background on which is superimposed a spectrum of bright lines. At this stage H. G. J. Moseley began a research with the intention of deciding whether the properties of an element depended on its nuclear charge rather than on its atomic weight as ordinarily supposed. For this purpose the X-ray spectra emitted by a number of elements were examined and found to be all similar in type. The frequency of a given line was found to vary very nearly as the square of a whole number which varied by unity in passing from one element to the next. Moseley identified this whole number with the atomic or ordinal number of the elements when arranged in increasing order of atomic weight, allowance being made for the known anomalies in the periodic table and for certain gaps corresponding to possible but missing elements. He concluded that

the atomic number of an element was a measure of its nuclear charge, and the correctness of this deduction has been recently verified by Chadwick by direct experiments on the scattering of α particles. Moseley's discovery is of fundamental importance, for it not only fixes the number of electrons in all the atoms, but shows conclusively that the properties of an atom, as had been surmised, are determined not by its atomic weight but by its nuclear charge. A relation of unexpected simplicity is thus found to hold between the elements. No one could have anticipated that with few exceptions all atomic numbers between hydrogen 1 and uranium 92 would correspond to known elements. The great power of Moseley's law in fixing the atomic number of an element is well illustrated by the recent discovery by Coster and Hevesy in Copenhagen of the missing element of atomic number 72, which they have named "hafnium."

Once the salient features of the structure of atoms have been fixed and the number of electrons known, the further study of the structure of the atom falls naturally into two great divisions: One, the arrangement of the outer electrons which controls the main physical and chemical properties of an element, and the other the structure of the nucleus on which the mass and radioactivity of the atom depends. On the nuclear theory the hydrogen atom is of extreme simplicity, consisting of a singly-charged positive nucleus with only one attendant electron. The position and motions of the single electron must account for the complicated optical spectrum, and whatever physical and chemical properties are to be attributed to the hydrogen atom. The first definite attack on the problem of the electronic structure of the atom was made by Niels Bohr. He saw clearly that, if this simple constitution was assumed, it is impossible to account for the spectrum of hydrogen on the classical electrical theories, but that a radical departure from existing views was necessary. For this purpose he applied to the atom the essential ideas of the quantum theory which had been developed by Planck for other purposes, and had been found of great service in explaining many fundamental difficulties in other branches of science. On Planck's theory radiation is emitted in definite units or quanta, in which the energy E of a radiation is equal to $h\nu$ where ν is the frequency of the radiation measured by the ordinary methods and h a universal constant. This quantum of radiation is not a definite fixed unit like the atom of electricity, for its magnitude depends on the frequency of the radiation. For example, the energy of a quantum is small for visible light, but becomes large for radiation of high frequency corresponding to the X rays or the γ rays from radium.

Time does not allow me to discuss the underlying meaning of the quantum theory or the difficulties connected with it. Certain aspects

of the difficulties were discussed in the presidential address before this association by Sir Oliver Lodge at Birmingham in 1913. It suffices to say that this theory has proved of great value in several branches of science, and is supported by a large mass of direct experimental evidence.

In applying the quantum theory to the structure of the hydrogen atom Bohr supposed that the single electron could move in a number of stable orbits, controlled by the attractive force of the nucleus, without losing energy by radiation. The position and character of these orbits were defined by certain quantum relations depending on one or more whole numbers. It was assumed that radiation was only emitted when the electron for some reason was transferred from one stable orbit to another of lower energy. In such a case it was supposed that a homogeneous radiation was emitted of frequency ν determined by the quantum relation $E=h\nu$ where E was the difference of the energy of the electron in the two orbits. Some of these possible orbits are circular, others elliptical, with the nucleus as a focus, while if the change of mass of the electron with velocity is taken into account the orbits, as Sommerfeld showed, depend on two quantum numbers, and are not closed, but consist of a nearly elliptical orbit slowly rotating round the nucleus. In this way it is possible not only to account for the series relations between the bright lines of the hydrogen spectrum, but also to explain the fine structure of the lines and the very complicated changes observed when the radiating atoms are exposed in a strong magnetic or electric field. Under ordinary conditions the electron in the hydrogen atom rotates in a circular orbit close to the nucleus, but if the atoms are excited by an electric discharge or other suitable method, the electron may be displaced and occupy any one of the stable positions specified by the theory. In a radiating gas giving the complete hydrogen spectrum there will be present many different kinds of hydrogen atoms, in each of which the electron describes one of the possible orbits specified by the theory. On this view it is seen that the variety of modes of vibration of the hydrogen atom is ascribed, not to complexity of the structure of the atom, but to the variety of stable orbits which an electron may occupy relative to the nucleus. This novel theory of the origin of spectra has been developed so as to apply not only to hydrogen but to all the elements, and has been instrumental in throwing a flood of light on the relations and origin of their spectra, both X ray and optical. The information thus gained has been applied by Bohr to determine the distribution of the electrons round the nucleus of any atom. The problem is obviously much less complicated for hydrogen than for a heavy atom, where each of the large number of electrons present acts on the

other, and where the orbits described are much more intricate than the orbit of the single electron in hydrogen. Notwithstanding the great difficulties of such a complicated system of electrons in motion, it has been possible to fix the quantum numbers that characterize the motion of each electron, and to form at any rate a rough idea of the character of the orbit.

These planetary electrons divide themselves up into groups, according as their orbits are characterized by one or more equal quantum numbers. Without going into detail a few examples may be given to illustrate the conclusions which have been reached. As we have seen, the first element hydrogen has a nuclear charge of 1 and 1 electron; the second, helium, has a charge 2 and 2 electrons, moving in coupled orbits on the detailed nature of which there is still some uncertainty. These two electrons form a definite group, known as the K group, which is common to all the elements except hydrogen. For increasing nuclear charge the K group of electrons retain their characteristics, but move with increasing speed, and approach closer to the nucleus. As we pass from helium of atomic number 2 to neon, number 10, a new group of electrons is added consisting of two subgroups, each of four electrons, together called the L group. This L group appears in all atoms of higher atomic number, and, as in the case of the K group, the speed of motion of the electrons increases, and the size of their orbits diminishes with the atomic number. When once the L group has been completed a new and still more complicated M group of electrons begins forming outside it, and a similar process goes on until uranium, which has the highest atomic number, is reached.

It may be of interest to try to visualize the conception of the atom we have so far reached by taking for illustration the heaviest atom, uranium. At the center of the atom is a minute nucleus surrounded by a swirling group of 92 electrons, all in motion in definite orbits and occupying but by no means filling a volume very large compared with that of the nucleus. Some of the electrons describe nearly circular orbits round the nucleus; others, orbits of a more elliptical shape whose axes rotate rapidly round the nucleus. The motion of the electrons in the different groups is not necessarily confined to a definite region of the atom, but the electrons of one group may penetrate deeply into the region mainly occupied by another group, thus giving a type of interconnection or coupling between the various groups. The maximum speed of any electron depends on the closeness of the approach to the nucleus, but the outermost electron will have a minimum speed of more than 1,000 kilometers per second, while the innermost K electrons have an average speed of more than 150,000 kilometers per second, or half the

speed of light. When we visualize the extraordinary complexity of the electronic system we may be surprised that it has been possible to find any order in the apparent medley of motions.

In reaching these conclusions, which we owe largely to Professor Bohr and his coworkers, every available kind of data about the different atoms has been taken into consideration. A study of the X-ray spectra, in particular, affords information of great value as to the arrangement of the various groups in the atom, while the optical spectrum and general chemical properties are of great importance in deciding the arrangements of the superficial electrons. While the solution of the grouping of the electrons proposed by Bohr has been assisted by considerations of this kind, it is not empirical in character, but has been largely based on general theoretical considerations of the orbits of electrons that are physically possible on the generalized quantum theory. The real problem involved may be illustrated in the following way. Suppose the gold nucleus be in some way stripped of its attendant 79 electrons and that the atom is reconstituted by the successive addition of electrons one by one. According to Bohr the atom will be reorganized in one way only, and one group after another will successively form and be filled up in the manner outlined. The nucleus atom has often been likened to a solar system where the sun corresponds to the nucleus and the planets to the electrons. The analogy, however, must not be pressed too far. Suppose, for example, we imagined that some large and swift celestial visitor traverses and escapes from our solar system without any catastrophe to itself or the planets. There will inevitably result permanent changes in the lengths of the month and year, and our system will never return to its original state. Contrast this with the effect of shooting an electron or a particle through the electronic structure of the atom. The motion of many of the electrons will be disturbed by its passage, and in special cases an electron may be removed from its orbit and hurled out of its atomic system. In a short time another electron will fall into the vacant place from one of the outer groups, and this vacant place in turn will be filled up, and so on until the atom is again reorganized. In all cases the final state of the electronic system is the same as in the beginning. This illustration also serves to indicate the origin of the X rays excited in the atom, for these arise in the process of reformation of an atom from which an electron has been ejected, and the radiation of highest frequency arises when the electron is removed from the K group.

It is possibly too soon to express a final opinion on the accuracy of this theory which defines the outer structure of the atom, but there can be no doubt that it constitutes a great advance. Not only does it offer a general explanation of the optical and X-ray spectra of the

atom but it accounts in detail for many of the most characteristic features of the periodic law of Mendeleeff. It gives us for the first time a clear idea of the reason for the appearance in the family of elements of groups of consecutive elements with similar chemical properties, such as the groups analogous to the iron group and the unique group of rare earths. The theory of Bohr, like all living theories, has not only correlated a multitude of isolated facts known about the atom, but has shown its power to predict new relations which can be verified by experiment. For example, the theory predicted the relations which must subsist between the Rydberg constants of the arc and spark spectra, and generally between all the successive optical spectra of an element, a prediction so strikingly confirmed by Paschen's work on the spectrum of doubly ionized aluminium and Fowler's work on the spectrum of trebly ionized silicon. Finally it predicted with such great confidence the chemical properties of the missing element, number 72, that it gave the necessary incentive for its recent discovery.

While the progress of our knowledge of the outer structure of atoms has been much more rapid than could have been anticipated, we clearly see that only a beginning has been made on this great problem, and that an enormous amount of work is still required before we can hope to form anything like a complete picture even of the outer structure of the atom. We may be confident that the main features of the structure are clear, but in a problem of such great complexity progress in detail must of necessity be difficult and slow.

We have not so far referred to the very difficult question of the explanation on this theory of the chemical combination of atoms. In fact, as yet the theory has hardly concerned itself with molecular structure. On the chemical side, however, certain advances have already been made, notably by G. N. Lewis, Kossel, and Langmuir, in the interpretation of the chemical evidence by the idea of shared electrons, which play a part in the electronic structure of two combined atoms. There can be little doubt that the next decade will see an intensified attack by physicists and chemists on this very important but undoubtedly very complicated question.

Before leaving this subject, it may be of interest to refer to certain points in Bohr's theory of a more philosophical nature. It is seen that the orbits and energies of the various groups of electrons can be specified by certain quantum numbers and the nature of the radiation associated with a change of orbit can be defined. But at the same time we can not explain why these orbits are alone permissible under normal conditions, or understand the mechanism by which radiation is emitted. It may be quite possible to formulate accurately the energy relation of the electrons in the atom on a simple theory,

and to explain in considerable detail all the properties of an atom, without any clear understanding of the underlying processes which lead to these results. It is natural to hope that with advance of knowledge we may be able to grasp the details of the process which leads to the emission of radiation, and to understand why the orbits of the electrons in the atom are defined by the quantum relations. Some, however, are inclined to take the view that in the present state of knowledge it may be quite impossible in the nature of things to form that detailed picture in space and time of successive events that we have been accustomed to consider as so important a part of a complete theory. The atom is naturally the most fundamental structure presented to us. Its properties must explain the properties of all more complicated structures, including matter in bulk, but we may not, therefore, be justified in expecting that its processes can be explained in terms of concepts derived entirely from a study of molar properties. The atomic processes involved may be so fundamental that a complete understanding may be denied us. It is early yet to be pessimistic on this question, for we may hope that our difficulties may any day be resolved by further discoveries.

We must now turn our attention to that new and comparatively unexplored territory, the nucleus of the atom. In a discussion on the structure of the atom ten years ago, in answer to a question on the structure of the nucleus, I was rash enough to say that it was a problem that might well be left to the next generation, for at that time there seemed to be few obvious methods of attack to throw light on its constitution. While much more progress has been made than appeared possible at that time, the problem of the structure of the nucleus is inherently more difficult than the allied problem already considered of the structure of the outer atom, where we have a wealth of information obtained from the study of light and X-ray spectra and from the chemical properties to test the accuracy of our theories.

In the case of the nucleus, we know its resultant charge, fixed by Moseley's law, and its mass, which is very nearly equal to the mass of the whole atom, since the mass of the planetary electrons is relatively very small and may for most purposes be neglected. We know that the nucleus is of size minute compared with that of the whole atom, and can with some confidence set a maximum limit to its size. The study of radioactive bodies has provided us with very valuable information on the structure of the nucleus, for we know that the α and β particles must be expelled from it, and there is strong evidence that the very penetrating γ rays represent modes of vibration of the electrons contained in its structure. In the long series of transformations which occur in the uranium atom, eight

α particles are emitted and six electrons, and it seems clear that the nucleus of a heavy atom is built up, in part at least, of helium nuclei and electrons. It is natural to suppose that many of the ordinary stable atoms are constituted in a similar way. It is a matter of remark that no indication has been obtained that the lightest nucleus, viz, that of hydrogen, is liberated in these transformations, where the processes occurring are of so fundamental a character. At the same time, it is evident that the hydrogen nucleus must be a unit in the structure of some atoms, and this has been confirmed by direct experiment. Mr. Chadwick and I have observed that swift hydrogen nuclei are released from the elements boron, nitrogen, flourine, sodium, aluminium, and phosphorus when they are bombarded by swift α particles, and there is little room for doubt that these hydrogen nuclei form an essential part of the nuclear structure. The speed of ejection of these nuclei depends on the velocity of the α particle and on the element bombarded. It is of interest to note that the hydrogen nuclei are liberated in all directions, but the speed in the backward direction is always somewhat less than in the direction of the α particle. Such a result receives a simple explanation if we suppose that the hydrogen nuclei are not built into the main nucleus but exist as satellites probably in motion round a central core. There can be no doubt that bombardment by α particles has effected a veritable disintegration of the nuclei of this group of elements. It is significant that the liberation of hydrogen nuclei only occurs in elements of odd atomic number, viz, 5, 7, 9, 11, 13, 15, the elements of even number appearing quite unaffected. For a collision of an α particle to be effective, it must either pass close to the nucleus or actually penetrate its structure. The chance of this is excessively small on account of the minute size of the nucleus. For example, although each individual α particle will pass through the outer structure of more than 100,000 atoms of aluminium in its path, it is only about one α particle in a million that gets close enough to the nucleus to effect the liberation of its hydrogen satellite.

This artificial disintegration of elements by α particles takes place only on a minute scale, and its observation has only been possible by the counting of individual swift hydrogen nuclei by the scintillations they produce in zinc sulphide.

These experiments suggest that the hydrogen nucleus or proton must be one of the fundamental units which build up a nucleus, and it seems highly probable that the helium nucleus is a secondary building unit composed of the very close union of four protons and two electrons. The view that the nuclei of all atoms are ultimately built up of protons of mass nearly one and of electrons has been strongly supported and extended by the study of *isotopes*. It was

early observed that some of the radioactive elements which showed distinct radioactive properties were chemically so alike that it was impossible to effect their separation when mixed together. Similar elements of this kind were called "isotopes" by Soddy, since they appeared to occupy the same place in the periodic table. For example, a number of radioactive elements in the uranium and thorium series have been found to have physical and chemical properties identical with those of ordinary lead, but yet to have atomic weights differing from ordinary lead, and also distinctive radioactive properties. The nuclear theory of the atom offers at once a simple interpretation of the relation between isotopic elements. Since the chemical properties of an element are controlled by its nuclear charge and little influenced by its mass, isotopes must correspond to atoms with the same nuclear charge but of different nuclear mass. Such a view also offers a simple explanation why the radioactive isotopes show different radioactive properties, for it is to be anticipated that the stability of a nucleus will be much influenced by its mass and arrangement.

Our knowledge of isotopes has been widely extended in the last few years by Aston, who has devised an accurate direct method for showing the presence of isotopes in the ordinary elements. He has found that some of the elements are "pure"—i. e., consist of atoms of identical mass—while others contain a mixture of two or more isotopes. In the case of the isotopic elements, the atomic mass, as ordinarily measured by the chemist, is a mean value depending on the atomic masses of the individual isotopes and their relative abundance. These investigations have not only shown clearly that the number of distinct species of atoms is much greater than was supposed but have brought out a relation between the elements of great interest and importance. The atomic masses of the isotopes of most of the elements examined have been found, to an accuracy of about one in a thousand, to be whole numbers in terms of oxygen, 16. This indicates that the nuclei are ultimately built up of protons of mass very nearly one and of electrons. It is natural to suppose that this building unit is the hydrogen nucleus, but that its average mass in the complex nucleus is somewhat less than its mass in the free state owing to the close packing of the charged units in the nuclear structure. We have already seen that the helium nucleus of mass 4 is probably a secondary unit of great importance in the building up of many atoms, and it may be that other simple combinations of protons and electrons of mass 2 and 3 occur in the nucleus, but these have not been observed in the free state.

While the masses of the majority of the isotopes are nearly whole numbers, certain cases have been observed by Aston where this rule

is slightly departed from. Such variations in mass may ultimately prove of great importance in throwing light on the arrangement and closeness of packing of the protons and electrons, and for this reason it is to be hoped that it may soon prove possible to compare atomic masses of the elements with much greater precision even than at present.

While we may be confident that the proton and the electron are the ultimate units which take part in the building up of all nuclei, and can deduce with some certainty the number of protons and electrons in the nuclei of all atoms, we have little, if any, information on the distribution of these units in the atom or on the nature of the forces that hold them in equilibrium. While it is known that the law of the inverse square holds for the electrical forces some distance from the nucleus, it seems certain that this law breaks down inside the nucleus. A detailed study of the collisions between α particles and hydrogen atoms, where the nuclei approach very close to each other, shows that the forces between nuclei increase ultimately much more rapidly than is to be expected from the law of the inverse square, and it may be that new and unexpected forces may come into importance at the very small distances separating the protons and electrons in the nucleus. Until we gain more information on the nature and law of variation of the forces inside the nucleus, further progress on the detailed structure of the nucleus may be difficult. At the same time, there are still a number of hopeful directions in which an attack may be made on this most difficult of problems. A detailed study of the γ rays from radioactive bodies may be expected to yield information as to the motion of the electrons inside the nucleus, and it may be, as Ellis has suggested, that quantum laws are operative inside as well as outside the nucleus. From a study of the relative proportions of the elements in the earth's crust, Harkins has shown that elements of even atomic number are much more abundant than elements of odd number, suggesting a marked difference of stability in these two classes of elements. It seems probable that any process of stellar evolution must be intimately connected with the building up of complex nuclei from simpler ones, and its study may thus be expected to throw much light on the evolution of the elements.

The nucleus of a heavy atom is undoubtedly a very complicated system, and in a sense a world of its own, little, if at all, influenced by the ordinary physical and chemical agencies at our command. When we consider the mass of a nucleus compared with its volume it seems certain that its density is many billions of times that of our heaviest element. Yet, if we could form a magnified picture of the nucleus, we should expect that it would show a discontinuous structure, occu-

pied but not filled by the minute building units, the protons and electrons, in ceaseless rapid motion controlled by their mutual forces.

Before leaving this subject it is desirable to say a few words on the important question of the energy relations involved in the formation and disintegration of atomic nuclei, first opened up by the study of radioactivity. For example, it is well known that the total evolution of energy during the complete disintegration of 1 gram of radium is many millions of times greater than in the complete combustion of an equal weight of coal. It is known that this energy is initially mostly emitted in the kinetic form of swift α and β particles, and the energy of motion of these bodies is ultimately converted into heat when they are stopped by matter. Since it is believed that the radioactive elements were analogous in structure to the ordinary inactive elements the idea naturally arose that the atoms of all the elements contained a similar concentration of energy, which would be available for use if only some simple method could be discovered of promoting and controlling their disintegration. This possibility of obtaining new and cheap sources of energy for practical purposes was naturally an alluring prospect to the lay and scientific man alike. It is quite true that, if we were able to hasten the radioactive processes in uranium and thorium so that the whole cycle of their disintegration could be confined to a few days instead of being spread over thousands of millions of years, these elements would provide very convenient sources of energy on a sufficient scale to be of considerable practical importance. Unfortunately, although many experiments have been tried, there is no evidence that the rate of disintegration of these elements can be altered in the slightest degree by the most powerful laboratory agencies. With increase in our knowledge of atomic structure there has been a gradual change of our point of view on this important question, and there is by no means the same certainty to-day as a decade ago that the atoms of an element contain hidden stores of energy. It may be worth while to spend a few minutes in discussing the reason for this change in outlook. This can best be illustrated by considering an interesting analogy between the transformation of a radioactive nucleus and the changes in the electron arrangement of an ordinary atom. It is now well known that it is possible by means of electron bombardment or by appropriate radiation to excite an atom in such a way that one of its superficial electrons is displaced from its ordinary stable position to another temporarily stable position further removed from the nucleus. This electron in course of time falls back into its old position, and its potential energy is converted into radiation in the process. There is some reason for believing that the electron has a definite average life in the displaced position, and that the chance of its return to its original position is governed by the laws of proba-

bility. In some respects an "excited" atom of this kind is thus analogous to a radioactive atom, but of course the energy released in the disintegration of a nucleus is of an entirely different order of magnitude from the energy released by return of the electron in the excited atom. It may be that the elements, uranium and thorium, represent the sole survivals in the earth to-day of types of elements that were common in the long-distant ages, when the atoms now composing the earth were in course of formation. A fraction of the atoms of uranium and thorium formed at that time has survived over the long interval on account of their very slow rate of transformation. It is thus possible to regard these atoms as having not yet completed the cycle of changes which the ordinary atoms have long since passed through, and that the atoms are still in the "excited" state where the nuclear units have not yet arranged themselves in positions of ultimate equilibrium, but still have a surplus of energy which can only be released in the form of the characteristic radiation from active matter. On such a view, the presence of a store of energy ready for release is not a property of all atoms, but only of a special class of atoms like the radioactive atoms which have not yet reached the final state for equilibrium.

It may be urged that the artificial disintegration of certain elements by bombardment with swift α particles gives definite evidence of a store of energy in some of the ordinary elements, for it is known that a few of the hydrogen nuclei, released from aluminium, for example, are expelled with such swiftness that the particle has a greater individual energy than the α particle which causes their liberation. Unfortunately, it is very difficult to give a definite answer on this point until we know more of the details of this disintegration.

On the other hand, another method of attack on this question has become important during the last few years, based on the comparison of the relative masses of the elements. This new point of view can best be illustrated by a comparison of the atomic masses of hydrogen and helium. As we have seen, it seems very probable that helium is not an ultimate unit in the structure of nuclei but is a very close combination of four hydrogen nuclei and two electrons. The mass of the helium nucleus, 4.00 in terms of O=16, is considerably less than the mass 4.03 of four hydrogen nuclei. On modern views there is believed to be a very close connection between mass and energy, and this loss in mass in the synthesis of the helium nucleus from hydrogen nuclei indicates that a large amount of energy in the form of radiation has been released in the building of the helium nucleus from its components. It is easy to calculate from this loss of mass that the energy set free in forming 1

gram of helium is large even compared with that liberated in the total disintegration of 1 gram of radium. For example, calculation shows that the energy released in the formation of 1 pound of helium gas is equivalent to the energy emitted in the complete combustion of about 8,000 tons of pure carbon. It has been suggested by Eddington and Perrin that it is mainly to this source of energy that we must look to maintain the heat emission of the sun and hot stars over long periods of time. Calculations of the loss of heat from the sun show that this synthesis of helium need only take place slowly in order to maintain the present rate of radiation for periods of the order of 1,000 million years. It must be acknowledged that these arguments are somewhat speculative in character, for no certain experimental evidence has yet been obtained that helium can be formed from hydrogen.

The evidence of the slow rate of stellar evolution, however, certainly indicates that the synthesis of helium and perhaps other elements of higher atomic weight may take place slowly in the interior of hot stars. While in the electric discharge through hydrogen at low pressure we can easily reproduce the conditions of the interior of the hottest star, as far as regards the energy of motion of the electrons and hydrogen nuclei, we can not hope to reproduce that enormous density of radiation which must exist in the interior of a giant star. For this and other reasons it may be very difficult or even impossible, to produce helium from hydrogen under laboratory conditions.

If this view of the great heat emission in the formation of helium be correct, it is clear that the helium nucleus is the most stable of all nuclei, for an amount of energy corresponding to three or four α particles would be required to disrupt it into its components. In addition, since the mass of the proton in nuclei is nearly 1.000 instead of its mass 1.0072 in the free state, it follows that much more energy must be put into the atom than will be liberated by its disintegration into its ultimate units. At the same time, if we consider an atom of oxygen, which may be supposed to be built up of four helium nuclei as secondary units, the change of mass, if any, in its synthesis from already formed helium nuclei is so small that we can not yet be certain whether there will be a gain or loss of energy by its disintegration into helium nuclei, but in any case we are certain that the magnitude of the energy will be much less than for the synthesis of helium from hydrogen. Our information on this subject of energy changes in the formation or disintegration of atoms in general is as yet too uncertain and speculative to give any decided opinion on future possibilities in this direction, but I have

endeavored to outline some of the main arguments which should be taken into account.

I must now bring to an end my survey—I am afraid all too brief and inadequate—of this great period of advance in physical science. In the short time at my disposal it has been impossible for me, even if I had the knowledge, to refer to the great advances made during the period under consideration in all branches of pure and applied science. I am well aware that in some departments the progress made may justly compare with that of my own subject. In these great additions to our knowledge of the structure of matter every civilized nation has taken an active part, but we may be justly proud that this country has made many fundamental contributions. With this country I must properly include our dominions overseas, for they have not been behindhand in their contributions to this new knowledge. It is, I am sure, a matter of pride to this country that the scientific men of our dominions have been responsible for some of the most fundamental discoveries of this epoch, particularly in radioactivity.

This tide of advance was continuous from 1896, but there was an inevitable slackening during the war. It is a matter of good omen that in the last few years the old rate of progress has not only been maintained but even intensified, and there appears to be no obvious sign that this period of great advances has come to an end. There has never been a time when the enthusiasm of the scientific workers was greater, or when there was a more hopeful feeling that great advances were imminent. This feeling is no doubt in part due to the great improvement during this epoch of the technical methods of attack, for problems that at one time seemed unattackable are now seen to be likely to fall before the new methods. In the main the epoch under consideration has been an age of experiment, where the experimenter has been the pioneer in the attack on new problems. At the same time it has been also an age of bold ideas in theory, as the quantum theory and the theory of relativity so well illustrate.

I feel it is a great privilege to have witnessed this period, which may almost be termed the renaissance of physics. It has been of extraordinary intellectual interest to watch the gradual unfolding of new ideas and the ever-changing methods of attack on difficult problems. It has been of great interest, too, to note the comparative simplicity of the ideas that have ultimately emerged. For example, no one could have anticipated that the general relation between the elements would prove to be of so simple a character as we now believe it to be. It is an illustration of the fact that nature appears to work in a simple way, and that the more fundamental the problem often

simpler are the conceptions needed for its explanation. The rapidity and certitude of the advance in this epoch have largely depended on the fact that it has been possible to devise experiments so that few variables were involved. For example, the study of the structure of the atom has been much facilitated by the possibility of examining the effects due to a single atom of matter, or, as in radioactivity or X rays, of studying processes going on in the individual atom which were quite uninfluenced by external conditions.

In watching the rapidity of this tide of advance in physics I have become more and more impressed by the power of the scientific method of extending our knowledge of nature. Experiment, directed by the disciplined imagination either of an individual, or still better, of a group of individuals of varied mental outlook, is able to achieve results which far transcend the imagination alone of the greatest natural philosopher. Experiment without imagination, or imagination without recourse to experiment, can accomplish little, but, for effective progress, a happy blend of these two powers is necessary. The unknown appears as a dense mist before the eyes of men. In penetrating this obscurity we can not invoke the aid of supermen, but must depend on the combined efforts of a number of adequately trained ordinary men of scientific imagination. Each in his own special field of inquiry is enabled by the scientific method to penetrate a short distance, and his work reacts upon and influences the whole body of other workers. From time to time there arises an illuminating conception, based on accumulated knowledge, which lights up a large region and shows the connection between these individual efforts, so that a general advance follows. The attack begins anew on a wider front, and often with improved technical weapons. The conception which led to this advance often appears simple and obvious when once it has been put forward. This is a common experience, and the scientific man often feels a sense of disappointment that he himself had not foreseen a development which ultimately seems so clear and inevitable.

The intellectual interest due to the rapid growth of science to-day can not fail to act as a stimulus to young men to join in scientific investigation. In every branch of science there are numerous problems of fundamental interest and importance which await solution. We may confidently predict an accelerated rate of progress of scientific discovery, beneficial to mankind certainly in a material but possibly even more so in an intellectual sense. In order to obtain the best results certain conditions must, however, be fulfilled. It is necessary that our universities and other specific institutions should be liberally supported, so as not only to be in a position to train adequately young investigators of promise, but also to serve themselves as active centers of research. At the same time there must be a

reasonable competence for those who have shown a capacity for original investigation. Not least, peace throughout the civilized world is as important for rapid scientific development as for general commercial prosperity. Indeed, science is truly international, and for progress in many directions the cooperation of nations is as essential as the cooperation of individuals. Science, no less than industry, desires a stability not yet achieved in world conditions.

There is an error far too prevalent to-day that science progresses by the demolition of former well-established theories. Such is very rarely the case. For example, it is often stated that Einstein's general theory of relativity has overthrown the work of Newton on gravitation. No statement could be farther from the truth. Their works, in fact, are hardly comparable, for they deal with different fields of thought. So far as the work of Einstein is relevant to that of Newton, it is simply a generalization and broadening of its basis; in fact, a typical case of mathematical and physical development. In general, a great principle is not discarded but so modified that it rests on a broader and more stable basis.

It is clear that the splendid period of scientific activity which we have reviewed to-night owes much of its success and intellectual appeal to the labors of those great men in the past, who wisely laid the sure foundations on which the scientific worker builds to-day, or to quote from the words inscribed in the dome of the National Gallery, "The works of those who have stood the test of ages have a claim to that respect and veneration to which no modern can pretend."

THE PHYSICIST'S PRESENT CONCEPTION OF AN ATOM[1]

By R. A. Millikan
Norman Bridge Laboratory of Physics

All scientists agree upon an atom which has a very minute positively charged nucleus surrounded in its outer regions by a number of negative electrons just sufficient to neutralize the free positive charge upon the nucleus.

We all agree that the number of these positive charges upon the nucleus varies from 1, in the case of hydrogen, by unit steps up to 92 in the case of uranium, and hence that the number of negatives held in the outer regions also varies from 1 to 92.

We all agree that the chemical properties of all atoms, and most of the physical properties, too, mass being the chief exception, are determined simply by the number of these electrons; primarily by the number of them which are found in the outermost shell and which we call the valence electrons.

We all agree, too, that the nucleus is extraordinarily minute, so that if all the dimensions of an atom were magnified ten billion times—a magnification which would make a bird shot swell to the size of the earth and would make the diameter of the atom about a meter—the nucleus, on this huge scale of magnification, would not be more than a tenth of a millimeter in diameter—that is, not larger than a mere pin point.

We all agree, too, that in the case of uranium there are packed into that infinitesimal nucleus 238 positive and 146 negative electrons, the exact number of positives being determined simply by the atomic weight, while the number of negatives which bind the positives is the atomic weight minus the atomic number. This obviously means that both positive and negative electrons are so infinitesimally small that for practical purposes we may ignore their dimensions altogether and think of them as mere point charges.

We all agree that so far as physical science has now gone there have appeared but these two fundamental entities, namely, positive

[1] An address delivered before the sixty-seventh convention of the American Chemical Society, Washington, D. C., Apr. 22, 1924. Reprinted by permission from Science, Vol. LIX, No. 1535, May 30, 1924.

and negative electrons[2] which seem to be the building stones of the universe; that these two entities are electrical charges of exactly the same magnitude, but of opposite sign, and that the mass or inertia associated with the former is 1,845 times that associated with the latter, so that practically the whole mass of the atom is concentrated in the positive electrons within its nucleus.

We all agree that when any of the electrons in the outer regions of the atom are stimulated to radiate, they do so by virtue of falling from a level of higher potential energy to one of lower, i. e., from a level more remote from the nucleus to one nearer to it.

And we all agree that the frequency of the emitted radiations is proportional to the energy loss in the process of changing from the one level to the other. Indeed, one of the most stimulating advances which physicists have made in the past five years consists in the complete demonstration of this Planck-Einstein-Bohr law of radiation. Very recent experiments go even so far as to indicate that this law holds not only for the radiations emitted by the changes in energy levels of the electrons outside the nucleus, but also for the radiations which originate in the nucleus itself—the so-called gamma rays which accompany changes within the nuclei of radioactive atoms.

These results upon which we all agree are proof enough of the amazing advances which have taken place, mostly within the past ten years, in our ability to peer inside the atom and to see what kind of entities exist there and what they are doing when they are in the act of radiating.

The only place where we have differences of opinion, or better, in which there are uncertainties, is in the matter of how the electrons spend their leisure time—the portions of their lives in which they are not radiating.

The chemist has in general been content with what I will call the "loafer" electron theory. He has imagined these electrons sitting around on dry goods boxes at every corner ready to shake hands with, or hold on to, similar electrons in other atoms. The physicist, on the other hand, has preferred to think of them as leading more active lives, playing ring-around-the-rosy, crack-the-whip, and other interesting games. In other words, he has pictured them as rotating with enormous speeds in orbits, and as occasionally flying out of these orbits for one reason or another.

[2] It is highly to be desired that this historically correct, etymologically most suitable, and authoritatively recognized nomenclature (see Rutherford's B. A. address 1923, Nernst's Physical Chemistry, last edition, etc.) be retained. When used without a prefix or qualifying adjective the word electron may signify both the generic thing, the unit electrical charge (this it does, in fact, signify both historically and derivatively), and at the same time the negative member of the species, in precisely the way in which the word man is used without a prefix to designate both the genus homo and also the male of the species. There is no gain in convenience by the use of the word proton and a distinct loss logically, etymologically, and historically.

Now the arguments for the "loafer electron" theory, as I have called it, are two in number. The first is that such activity as the physicist postulates would soon wear away all the energy possessed by the electrons—that is, they would tire themselves out and quit their play.

There is no answer to this argument. They would indeed tire themselves out, provided the classical electromagnetic laws are universally applicable—even in the hearts of atoms. And the physicist's only answer to this argument is, "God did not make electrons that way. Why assume that the electromagnetic laws are universally valid when this is the first chance we have had to test them out in the region of the infinitely small?"

The second argument which has been advanced for the "loafer electron" theory is the existence of localized valences in chemistry. Now, that these localized valences exist is admitted on all hands; but it is simply due to a misunderstanding that this argument was ever used against the orbit theory. For no physicist—and I wish to emphasize this fact—has ever advanced the theory that the electrons all rotate in coplanar orbits. Localized valences probably are just as compatible with the orbit theory when the orbits are properly distributed in space as with the stationary electron conception. All this I pointed out in 1916,[3] trying thereby to clear the misconception which existed in the minds of chemists as to the way in which physicists were thinking.

Let me pass now to the arguments in favor of the orbit theory. They are all of them definite quantitative arguments in which purely theoretical considerations lead to exact numerical predictions which can be subjected to the test of experiment.

The first was the exact prediction with the aid of *orbit equations* of the so-called Rydberg spectroscopic constant which is in agreement, with an accuracy of one part in five hundred, with the directly measured value.

The second quantitative argument comes from the prediction of a difference between the positions in two spectral lines, one due to helium, the other to hydrogen, which two lines should theoretically be one and the same line, if it were not for the fact that the helium nucleus is four times as massive as the hydrogen nucleus.

To make clear the difference which this causes let me ask you to reflect that when an electron revolves around the nucleus of an atom of hydrogen, the real thing that happens is that the two bodies revolve about their common center of gravity, but, since the nucleus is 2,000 times heavier than the electron, this center is exceedingly close to the hydrogen nucleus. If now the hydrogen nucleus is re-

[3] Phys. Rev., May, 1917; presented before the American Physical Society, Dec. 1, 1916.

placed by the nucleus of the helium atom, which is four times as heavy as that of hydrogen, the common center of gravity is still closer to the nucleus so that the helium nucleus describes a much smaller circle than does the hydrogen nucleus. This situation is responsible for a certain slight but accurately predictable difference in the energies of the two orbits which should cause the lines produced by electron jumps to these two different orbits to be slightly displaced from one another. This displacement is actually found between the corresponding hydrogen and helium lines, and the ratio of the mass of the electron to the mass of the hydrogen atom computed from this displacement agrees with other determinations of this ratio to within a small fraction of a per cent.

The third amazing quantitative success of the orbit theory came when Sommerfeld showed that the Bohr orbit theory ought to demand two different hydrogen orbits corresponding to the second quantum state, one a circle and one an ellipse. And by applying the relativity theory to the change in mass of the electron with its change in speed, as it moves through the different portions of its orbit, he showed that these two orbits should have slightly different energies, and consequently that both the hydrogen and the helium lines should be doublets.

Now not only is this found to be the fact, but the measured separation of these two doublet lines agrees precisely with the predicted value, so that this again constitutes an extraordinary bit of quantitative evidence for the validity of the orbit conceptions underlying the computation.

The fourth quantitative argument was introduced by Epstein when he applied his extraordinary grasp of orbit theory to the exceedingly difficult problem of computing the perturbations in electron orbits and hence the change in energy of each due to exciting hydrogen and helium atoms to radiate in an electrostatic field. He thus predicted the whole complex character of what we call the Stark effect, showing just how many new lines were to be expected and where each one should fall, and then the spectroscope yielded, in practically every detail, precisely the result which the Epstein theory had foretold.

The fifth quantitative success of the orbit theory is one which Mr. I. S. Bowen and myself at the California Institute have just brought to light. Through creating what we call "hot sparks" in extreme vacuum, we have succeeded in stripping in succession one, two, three, four, five, six, and seven of the valence, or outer, electrons from the atoms studied. In going from lithium through beryllium, boron and carbon to nitrogen, we have thus been able to play with stripped atoms of all these substances. Now the stripped atoms

constitute structures which are all exactly alike, save that the fields in which the single electron which is left is describing its orbit increase in the ratios one, two, three, four, five, as we go from stripped lithium to stripped nitrogen. Now we have applied the relativity doublet formula which, as indicated above, Sommerfeld had developed for the simple nucleus-electron system found in hydrogen and ionized helium, and have found that it not only predicts everywhere the observed doublet separation of the spectra produced by all these stripped atoms, but that it enables us to compute the effect which the two electrons close to the nucleus of all these atoms have in screening the outer rotating electron from this nucleus.

At a sufficient distance from the nucleus these two electrons ought to neutralize exactly two of the free positive charges on the nucleus, provided, and only provided, the forces emanating from these electrons fall off with the inverse square of the distance. Our relativity doublet formula, with this assumption and without the introduction of any arbitrary constants whatsoever, enabled us to predict what the screening effect due to those two electrons ought to be. And now our experiments on doublet separations reveal that that screening is within one per cent of two, which checks with what we knew beforehand, from radioactive and chemical data, that it ought to be. In other words, we have another method which enables us with certainty to look inside the atom and find how many electrons are in the inmost shell, and the answer comes out two.

Again, when we examine the spectrum due to the stripped atoms of the group of atoms from sodium to chlorine—one electron having been knocked off from sodium, two from magnesium, three from aluminium, four from silicon, five from phosphorus, six from sulphur, and seven from chlorine—we should find in every case that the number of screening electrons in the two inmost shells, when tested for sufficiently remote orbits, comes out two plus eight, i. e., ten. And it does come out in every case very nearly as predicted. This constitutes excellent evidence that the electrons at these distances and under these conditions do possess Coulomb fields (fields falling off with the inverse square of the distance), a result apparently incompatible with the loafer-electron theory. The physicist has thus piled Ossa on Pelion in his quantitative proof of the existence of these electron orbits.

These new results are, however, incompatible with the precise shapes of orbits with which the physicists have been working in the field of optics during the last five years. They necessitate either the abandonment of the relativity cause for the separation of our measured spectroscopic doublets or else they require us to

cease to play with a nucleus about which the electron orbits are largely symmetrical. In other words, if we retain the relativity explanation of the spectroscopic-doublet formula, we are obliged to suppose that two orbits which have the same shape but different orientations with respect to the nucleus may exhibit widely different screening constants—which is only another way of saying that these orbits may possess widely different energies.

To this extent, then, I am able to help out the chemist in his attack upon the electronic orbits of the physicists. I am able to enable him to say with a good deal of certainty that these orbits can not be of precisely the type which we physicists have been playing with so assiduously for the past five years. If we retain the explanation which has heretofore been given to the relativity doublet formula, an explanation which requires entirely different shapes for the two orbits corresponding to these doublets, then we must begin to work with an atom which is very much less symmetrical with respect to the differently oriented orbits than we have hitherto been imagining.

THE VACUUM—THERE'S SOMETHING IN IT[1]

By Dr. W. R. Whitney
Director, Research Laboratory, General Electric Co.

[With 5 plates]

We humans want better minds, broader horizons, and greater understanding. Scientists everywhere are at work in their respective fields searching for new truths to improve the process by which our minds, our horizons, our powers, and our outlooks grow.

When in the middle ages the great cathedrals of the world were being built the mentality of men seems to have been directed to systematic subordination of creation rather than to active appreciation of it; to acquiring salvation, or "safety first," rather than knowledge or understanding. To-day scientists, in seeking truth, think of "safety first" last.

We are told that if the total age of mankind be expressed as the life of a man of 50 years and, if he then looks back upon his progress, he will see that what marks his greatest advancement are events occurring in the most recent years. For example, such a 50-year man now sees that he had not learned to scratch the simplest records on stone until his forty-ninth year. All the immense advantages of printing have existed only three months for him. He has only just learned how to pass along what he has learned. The uses of steam, which now seem so necessary, were acquired only three or four days ago. The uses of electricity (street cars, lamps, and telephones), which did not actually begin until about 1880, arrived the day before yesterday to this 50-year man. The automobile, radio, X rays, radium, and most of the things which occupy our interests to-day were actually discovered on this particular fiftieth birthday.

The power outside of his own muscles, which during the past two or three months he has learned to control, has grown to nearly 20 horsepower, or 200 man power, for every man in the country. Therefore it makes only one-half a per cent difference whether all the men work like horses or not. But guidance of power is man work, because there are no machine mentalities. Almost everything but

[1] Reprinted by permission from General Electric Review, Vol. XXVII, No. 7, July, 1924.

thinking may be artificially done, but knowledge and understanding must be actively sought and used. Man is the only animal that can do this.

Scientists know that research merely discloses new parts of the infinite unknown. Paradoxically, the enticing, helpful "unknown" increases as men continue to subtract from it. Progress in every line of experimental science follows the same law. The apparently narrow path gradually expands into unlimited, unexplored territory. With his new tools and his increased speed of communication man finds that he can advance into the unknown faster than his ancestors could, and children seem to learn more rapidly than he did when he was young. The scientists of the twentieth century are legion. But scientists were anathema a short time ago. There is to-day more chemistry in the atom than there was in all "inorganic" chemistry a few years ago. There is more in the "sugars" now than there was in all "organic" when the writer studied it. There is more immunity in blood and more heredity in the microscopic chromosome than there was in all biology until recently. There is more crystal structure research by X rays now than research in all mineralogy when Agassiz came to America.

In the preparation of an article the purpose of which is to direct attention to the interest connected with research work in general there is special reason for selecting as the subject such a narrow field as the vacuum. The writer wishes to show that in a vacuum, of which one might say "There is nothing in it" (and surely less than in anything else), there is, indeed, an endless amount of interest and utility. The American public now buys over a million dollars' worth of glass vacua a week, but that is the least interesting part of the subject.

Everybody pretends to know that "Nature abhors a vacuum." But he who started that tale merely meant that a good vacuum was hard to produce. As probably no one has ever made a vacuum with less gas molecules in a cubic inch than there are people in the world, we can maintain that perfection in vacua is still precluded by nature.

Some studies in vacua will now be reviewed for the purpose of showing that anyone may well do research work not only there but also certainly anywhere else with pleasure and profit.

We all know that we see at night largely by the aid of vacuum lamps. Through other vacuum lamps, called X-ray tubes, we also see through opaque bodies. The light which illumines our microscope specimen has its analogue in the X-ray light, which shows us the crystal structure of matter and the electrical formulas of chemical atoms. Our transcontinental wired telephony is possible through vacuum tubes which, in various forms, also permit our radio broadcasting and radio reception from the most remote stations. The

workman who keeps his drink hot or cold in a thermos bottle is clearly indebted to Sir James Dewar's application of the vacuum, but the scientist is still more indebted to it. All our steam-power plants, including turbines, owe their success to vacua.

The latest arrival in the family of the chemical elements (hafnium) was discovered by trying it in vacuum as an X-ray target. Our list of possible chemical elements was rounded off by Moseley's study of the X-ray spectra just in time to meet the wonderful discoveries of J. J. Thomson and Aston, all made in vacua. The latter showed that most of the elements, supposedly simple, are still mixtures of two or more similar elements (isotopes), while Professor Thomson's experiments disclosed by the positive ray method a whole series of new atomic compounds.

While the vacuum was not essential to the work of Millikan in isolating the electron, yet the earlier work by Thomson and others and much of the recent work on this ultimate constituent of matter has been necessarily carried out in vacuum. To-day there seems to be no end to the studies which can be based on the fact that an atom or molecule of material may be separated electrically into a positively charged ion (carrying most of the mass) and a negatively charged electron (carrying most of the current).

ELECTRICITY

Without sacrificing historical truth too much, it may be asserted that electricity at rest was the first kind known. It then seems logical that electricity in simple direct motions should later appear and that still later we should find various directions and rates of its motion, if it moves at all. It will interrupt this line of argument if we doubt the existence of electricity as a thing or question the existence of such different kinds of it as static and dynamic. The electricity of rubbed amber was the first and stationary kind (if it is admitted that prior to Thales such things as lightning were something else). When electricity first moved through metals the process was looked upon as a simple directed flow which proceeded until the charged body had delivered its charge.

CURRENTS

This direct flow of electricity (a current) was strengthened in its hold on our conception by the great number of different chemical current producers which followed the controversies between Galvani and Volta a century and a quarter ago. Primary and secondary or storage batteries without number were soon discovered. The current from such batteries was exactly like that which the magneto-electric machines produced, when these were developed, after Faraday had shown the effect of moving a wire through a magnetic field.

The direct current of such generating machines was much later followed by the alternated flow, and soon alternating-current generators were made for different rates of reversal of direction. Sixty-cycle and twenty-five-cycle currents are now common, and the user takes his choice. These frequencies were once accidents of convenience and economy. For some uses other widely different frequencies of alternation are very desirable, as in radio, where 1,000,000 cycles are common.

Now the phenomena which have been found in vacuum tubes promise to give complete control over all these details of kind and frequency of current.

ELECTRICAL CONTROL

As will be more fully shown later, when a unidirectional current meets vacuum tubes as though it would pass through them, it must find one particular kind of a tube, and the current's direction must be right, because some tubes will let it through only when it is both unidirectional and in the proper direction. These in themselves are rather remarkable things to expect of a vacuum, but as usual the truth exceeds the expectation.

CATALYSIS

To give some idea of the extent to which vacuum studies may affect remote fields, mention may be made of chemical catalysis, the secret of most reactions of life. For example, it is known that mercury vapor in a vacuum, when illumined by light of a certain wave length, will absorb that light and turn the energy over to hydrogen, if hydrogen be present, so that this, in turn, will chemically reduce such substances as cold copper oxide. Here is a new kind of chemical process. It is the kind we have needed in order to begin to explain some of those life reactions which vegetation discloses. That is, similar facts will probably be found to contain the explanation of the catalytic action of sunlight on growing plants.

And so the studies of phenomena in vacua may lead us into the most widely separated fields. The experiments described in the latter part of this article are illustrations of this fact and are thus not chosen to be very closely related.

KINDS OF VACUA

One might say, as in our school-day essays, "There are different kinds of vacuum, too numerous to mention," and then proceed to mention them all. However, only a few cases will be selected for the purpose of illustration. A certain kind of vacuum is good enough for incandescent lamps, because other factors besides the

quality of its vacuum determine the death or limit the performance of a lamp. But while formerly the incandescent lamp represented the very highest skill then reached in vacuum production, there are now other commercial vacua which are necessarily quite superior. This is true of good thermos bottles, X-ray tubes, and radio tubes.

We should first, therefore, give brief consideration to the incandescent lamp and note a few characteristics. Its low vacuum early disclosed electric cross currents which would not have been found in much higher vacua. Study of these currents has led not only to the vacuum tubes used in radio, but also to such remote disclosures as that distillation or evaporation of solids in vacuum proceeds in straight lines. The electrical currents in poor vacua are best known in luminous Geissler tubes, Moore tubes, and Claude tubes, as seen on the streets of Paris, for example. They are themselves a large subject, but consideration will be given (later on) only to one historically important experiment with them, the Hittorf experiment.

HIGH VACUA

Electric currents through vacua, where gas is so completely removed that it has no appreciable action, are most strictly a part of this article. After the work by which the individual and indivisible negative electrical charge or electron was defined, it seemed quite fitting, though unexpected, to learn that these negative charges were exuded by hot bodies. The result of this disclosure formed the basis for most of the modern electrical phenomena in vacua. The activities of electrons are apparently the cause of most electrical and chemical processes. Their motion constitutes electric currents, and the currents are determined and controlled by voltage or potential difference.

Bees might illustrate electronics, though it's admittedly bad policy to push bees too hard. If bees represent electrons, then matter in general becomes the hives. When the hives are cold or in the dark the bees stay inside. Under the effect of heat or light the bees are induced to come out. Similarly highly heated matter, such as tungsten, exudes electrons; and at ordinary temperatures light induces electrons out of metallic potassium, for example.

What are the bees or electrons going to do after they are out of the hive (or the metal)? That depends on impulse or pressure. They will fly in that special direction which tends to relieve that particular pressure. They proceed down the gradient. The electrons coming out of the metal (because of heat or light) will also fly in that special direction which will tend to relieve the particular electrical pressure. They also proceed down the gradient. But if there

is no particular impulse or gradient, both bees and electrons hang around the source.

A lot of electrons, like bees, flying in a common direction, becomes a current or cathode ray. We might let them fly from the hot or lighted spot into a cold or dark one, and until we heated or lighted the latter they would not come out. This unidirectional current corresponds to what takes place in rectifiers and kenotrons, where we have impulses in two opposite directions between one hot and one cold electrode in vacuum. If the hives (or the electrodes) are equal in temperature or illumination, no differential in current is possible, and with alternating impulses alternating instead of pulsating direct current passes. Thus bees illustrate two-electrode vacuum devices.

In the three-electrode vacuum tubes the third electrode is a sort of grid, or open fence, located between the hot and cold electrodes. This grid lets electrons pass freely, except when it is negatively charged. Thus also the bees would pass through a wire fence when they might be stopped if their impulse to proceed could be suddenly removed there. The negative charge is used in the three-element tube to alter the intention of the migrating bees or electrons as often as desired, and this with the rapidity of light.

In the case of radio, it is the impulse from the antenna or loop, changing with every delicate change of voice-current or code-current, which, when led to the grid, charges it and thus controls the currents within the receiving tube. These controlled currents do the work in the telephone.

Everybody knows that radio tubes are very sensitive. One cat-power of electricity used in New York actually puts the impulses into a receiving outfit in San Francisco, and at the same time it also puts the identical impulses into millions of other receivers. But some appreciable energy must be used by each receiver to direct the local battery which operates the head sets. This minute quantity of energy may be made significant as follows:

If a house fly climbs up a window pane 1 inch, he does a definite amount of work in lifting his body that much. If this work constituted the supply fed into the receiving tube from space, it would suffice to actuate the outfit continuously for a quarter of a century. This might interest a future student of telepathy, if the time comes to determine how far the energy of one thought may influence thought in a distant brain. It has not been possible thus far to determine the quantity of energy which is expended in thought. Just keeping alive transfers so much energy into heat that the additional energy transferred when we think has been too small to detect. But it need not be small compared to the power sensitivity of a radio set.

VACUUM TUBES

The mere names of modern vacuum-tube applications of electrons are legion. The kenotron is a vacuum tube which changes high-voltage alternating current into direct current, and it has its counterpart for low voltages in the battery-charging tungar rectifier and the mercury rectifier. The various radiotrons, receivers, and amplifiers of radio are also the most direct applications of the action of negative electrons in good vacua. But X-ray tubes must also be considered in this connection, because X rays are the result of the "bump," if you will, of rapidly moving electrons in vacua against the atoms of matter.

Electrons in motion are also directed and controlled by electromagnetic, as well as by electrostatic, fields. Therefore the magnetron and axiotron have to be included. Because the mere illumination of such metals as potassium (like the high heating of other metals, such as platinum and tungsten) causes them to emit electrons, the photoelectric cell has to be included in our illustrations.

The electrons within the vacuum, as in a radio detector tube, obey the inconceivably feeble electrical impulses received by the antenna. Conversely, the motion of electrons sets up impulses and waves in space. In other words, the vacuum detector may be made a radio wave generator. Such tubes are used in broadcasting stations.

ETHER WAVES

The wave lengths of the magnetic waves produced by the changes of motion of the electrons are very long in the case of radio (say 100 to 10,000 feet), millions of times shorter in ordinary light, and millions of times shorter still in X rays, but they are all in the same medium and all due to motions of electrons.

SPECIAL EMISSIONS

Finally, to give an impression of the distance such work has gone, there should also be added the case of a one-atom-deep layer of thorium on tungsten in a vacuum and its effect on electron emission.

EXPERIMENTS

LAMPS

The first great use of vacuum was in incandescent lamps. If such a lamp is burned at much higher than its rated voltage, it lasts for a few minutes only, but it gives a light perhaps five times as efficient as we usually see. The lamp dies because the tungsten vaporizes or melts. The vacuum is not at fault. It is because of these limita-

tions that commercial lamps are so made that they burn at normal voltages on proper circuits an average of 1,000 hours. If we were satisfied with a shorter life we could have a more efficient lamp, but experience has shown that we would be unwilling to use the short-life lamps in order to secure the added efficiency. To increase the efficiency without shortening the life of lamps much study has been made of distillation of metals in vacua, and of methods for returning the distilled metal to the filament. Much has also been done to make the deposit on the glass invisible or white, so as not to interfere with light transmission. Naturally we are always on the lookout for metals, such as the newly discovered hafnium, which might possibly live longer as a filament than tungsten now lives. Thirty or forty years of research work had been spent on high-vacuum incandescent lamps before Doctor Langmuir showed us how to make still better lamps by putting back into the vacuum gases like argon and nitrogen.

DISTILLATION

When the material of a filament distills in vacuum it does not meet interference to the motion of its molecules, and the distilling substance proceeds in straight lines from the heated source. This is often observed when an incandescent vacuum lamp arcs or burns out. Metal shadows of interior parts of the lamp are then often cast onto the walls. This is shown more clearly when a metal like gold is evaporated from the surface of a tungsten filament in vacuum. By the interposing of a design, as, for instance, the star in the left-hand bulb of Plate 1, Figure 1, a shadow in gold is cast on the glass as shown on the right-hand bulb of Plate 1, Figure 1. This simple phenomenon is mentioned because it fits in with the kinetic theory of gases and explains many things observed in vacua. The "mean free path" of molecules or atoms is very long in good vacua, and so straight-line distillation occurs.

HITTORF BULBS

In the historic Hittorf experiment two vacuum bulbs, each carrying an electrode, were joined together by two glass tubes, one very short and one exceedingly long, as shown in Plate 1, Figure 2. When electric current was passed from one bulb to the other, it evidently chose the longer instead of the shorter path, because the longer tubes became highly luminous, while the shorter one did not. This is a quality of electrical conduction in vacua where small quantities of gases still remain, but it can not be gone into here.

EDISON EFFECT

Another experiment shows the historic Edison effect and its relationship to pure thermionic currents. Where it was once thought that nearly visible particles of the filament were shot across the space between filament legs in vacua, now we recognize, in very high vacua, only the unidirectional motion of negative electrons.

RECTIFIERS

In vacuum tubes like the kenotron these electrons pass from the hot filament to an electrode commonly called the "plate." This pure emission current is the basis for the so-called rectifiers because only when the filament is negative does any current flow across the space. When gases are present greater currents may be carried, because by the ionization of the gases the moving electrons produce new conductors from the gas molecules. Thus the tungar rectifiers, containing a little argon, and the older mercury vapor rectifiers involve the same principle. Without some gas present the negative electrons, by their very concentration, constitute a space charge which limits the current. This space charge is removed by the ions produced within the gas when present.

RADIOTRONS

When we interpose a grid or wire screen between the hot filament and the plate of the two-electrode tube or rectifier, we have what we now so commonly use in radio for receiving, for amplifying, and for production of high-frequency currents. The discovery of the controlling or triggering action of the third or intermediate electrode was made by De Forest. A negative charge applied to this electrode or grid interrupts or modifies the electron stream, the current, from the hot filament to the plate. As it takes almost no energy to charge this grid (little more than a "token" of energy, or voltage) the slight power from a radio antenna in its fluctuation may be used to control or to trigger or to let through corresponding jolts of greater energy, which are in turn supplied by some local battery. In the experiment illustrated in Plate 2, Figure 1, an ordinary incandescent lamp is lighted by current which is passing through a three-electrode tube from hot filament to plate. Its light indicates this current. The grid, or antenna wire, is sticking up from the tube so that it can "pick up" electric charges from space. A small negative charge, produced on a rod of insulating material by merely rubbing it with a piece of paper, causes the lamp to go out or to light up as the charged rod is brought near to or removed from the exposed end of the grid wire.

MAGNETRON

As the negatively charged grid cuts off the current of the three-element tube, so an external magnetic field will also do it in the two-element tube, by so influencing or directing the moving electrons that they can not reach the plate. Such a device is called a magnetron. The particular magnetron used in this experiment, Plate 2, Figure 2, consisting of a cylindrical plate in a vacuum and a central filament within it, has a coil of wire wound on the outside of the glass. A feeble current sent through the coil from a battery may be made to set up within this coil a magnetic field about equal to that of the earth's magnetic field, so that by moving the whole apparatus about in space (thereby at one time adding to the earth's field, at others opposing it) the magnitude and direction of the earth's magnetic field can be disclosed by a meter which indicates the resultant current. When the magnetron points toward the north pole, the meter shows no current, while in other positions currents are measured.

AXIOTRON

Another useful vacuum tube of this type is one in which the magnetic field of the filament current itself becomes great enough during each current cycle to deflect the electrons so that they will not reach the plate. By this tube, "the axiotron," the frequency of an alternating current may be doubled or direct current be changed into alternating.

PHOTO-ELECTRIC CELL

Another vacuum tube is the photo-electric cell. As shown in Plate 3, Figure 1, one of these may be connected with a relay to a lamp so that when light shines upon the cell the burning electric lamp is extinguished, and relighted on cutting off the light from the photo-electric cell. In other words, it turns on the lamp when it is dark and turns it off when it is light. This depends on the fact that some metals, like potassium, emit electrons when light falls upon them. These electrons in vacuum constitute a current when they are made to move by the electrical impulse. To repeat; applying potential to a vacuum tube having a potassium electrode and another electrode for leading off the current causes current to flow in the form of negative electrons from the illuminated metal, and this current actuates the electrical switch which turns off the lighting current of the burning lamp.

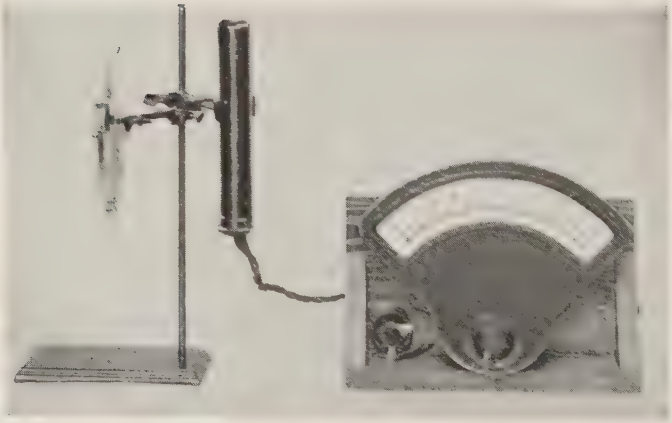
THE NERVE

This leads to the next, an ambitious physiological experiment As shown in Plate 3, Figure 2, a photo-electric cell may be made to

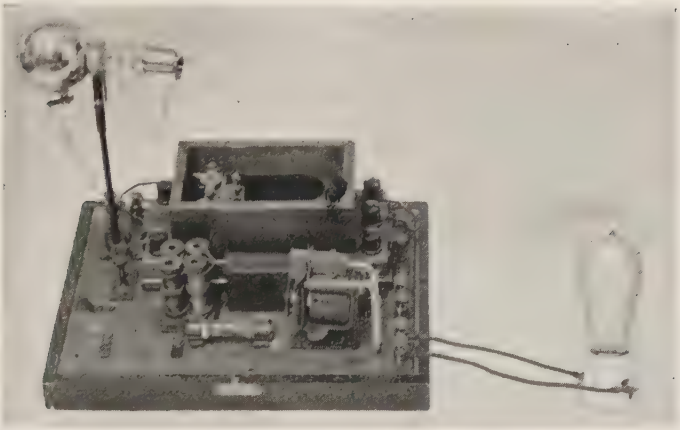
1. A Demonstration of the Straight-Line Distillation Which Takes Place in Good Vacua. In the Right-Hand Bulb, Which Has Inside Elements Duplicating Those in the Left-Hand Bulb, the Shadow Pattern of the Interposing Star Shows Clearly in the Film of Metal Distilled onto the Interior Wall

2. Hittorf Experiment in Which an Electric Current Passed from One Bulb to the Other at Low Gas Pressure Prefers the Longer of the Two Tube Paths

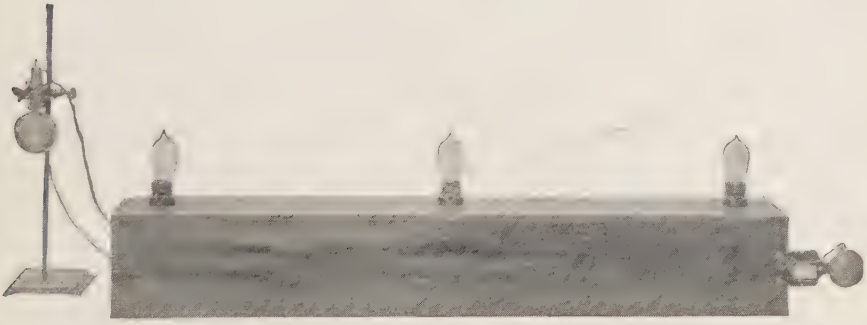
1. A Demonstration of the Radiotron Principle. Electron Current from the Hot Filament to the Plate of the Radiotron Tube on the Left Is Made to Light the Incandescent Lamp at the Right. This Current Can Be Stopped by Inducing a Negative Charge on the Vertical Antenna Wire Which Is Connected to the Grid



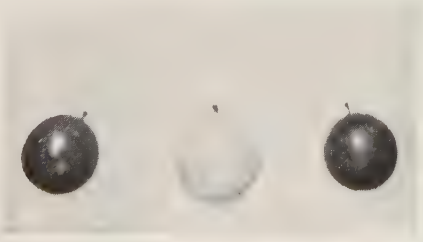
2. A Demonstration of the Sensitiveness of a Magnetron Tube to a Magnetic Field. When This Two-Element Tube Is Suitably Arranged, Its Position with Respect to Terrestrial Magnetism Influences the Meter Reading



1. A DEMONSTRATION OF THE ACTION OF A PHOTO-ELECTRIC CELL CONNECTED THROUGH A RELAY TO AN INCANDESCENT LAMP. WHEN NO LIGHT FALLS ON THE CELL, THE LAMP BURNS; WHEN THE CELL IS EXPOSED TO LIGHT, THE LAMP IS EXTINGUISHED



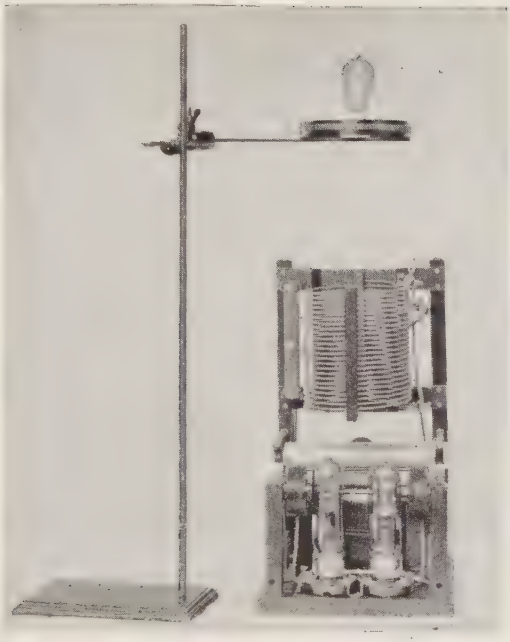
2. APPARATUS CONSISTING OF A PHOTO-ELECTRIC CELL, INDICATING LAMPS, CAPACITIES AND AMPLIFIERS (IN BOX), AND A DOORBELL ARRANGED TO DEMONSTRATE THE RETARDED TRANSMISSION OF AN IMPULSE, SUCH AS NERVE ACTION



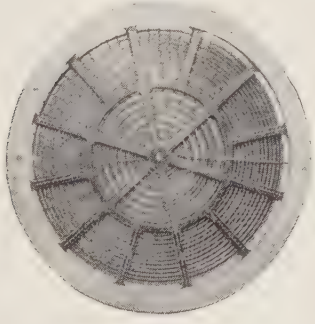
3. THREE SUSPENDED RUBBER BALLOONS REPELLING EACH OTHER TO A TRIANGULAR FORMATION AS THE RESULT OF BEING ELECTROSTATICALLY CHARGED. (SEE FIG. 1, PL. 4)

1. THE BALLOONS ILLUSTRATED IN FIGURE 2, PLATE 3, ARE HERE SHOWN IN THEIR NORMAL POSITIONS AS THE RESULT OF THEIR CHARGES HAVING BEEN DISSIPATED BY A FEEBLE BEAM OF X-RAYS

2. APPARATUS DEVISED TO DEMONSTRATE THE CHARACTERISTICS OF ELECTRON EMISSION FROM A THORIATED TUNGSTEN FILAMENT



1. A DEMONSTRATION OF THE TRANSMISSION OF ENERGY THROUGH SPACE BY MEANS OF WAVES OF SEVERAL MILLION CYCLES. THE LIGHTED LAMP ON THE STAND RECEIVES ITS ENERGY FROM THE SOURCE LOCATED BENEATH



2. THE HEWLETT LOUD SPEAKER. NO HORN IS NEEDED ON ACCOUNT OF THE LARGE SIZE OF THE DIAPHRAGM, 26 INCHES DIAMETER. THE ABSENCE OF THE HORN AND THE DISTRIBUTED EXCITING COIL MAKE REPRODUCTION POSSIBLE WITH A HIGH DEGREE OF FAITHFULNESS. FOR ITS OPERATION, A SET OF VACUUM TUBES AMPLIFIES THE MICROPHONE CURRENT

represent a crude "eye" which is connected to a so-called "nerve" leading to a "brain." The nerve is merely a long box having electrical capacities and suitable amplifiers or three-electrode tubes within. The capacities serve to slow down the apparent rate of flow of the feeble current from the artificial eye so that indicating lamps along the top of the box or "nerve" light up, one after another, as the impulse from the "eye" passes along that path, or the nerve. After the last lamp is thus lighted by these amplified currents an electric bell rings to indicate reception at the "brain" end of the circuit. This is not offered as a reliable replica of the real nervous system, but as an application of the vacuum tube which amplifies the slight energy available and necesary for the experiment. With such slight energy it becomes practicable to show the delayed transmission and reception which is necessary for an illustration of nerve action. Nerve impulses travel much slower than electricity usually does, and this low speed was one objection to visualizing nerves as electrical conductors until Crehore and Williams showed that nerves might be naturally so constructed as to transmit slowly.

X RAY

In order to show another vacuum product (the X-ray tube) an effect of X rays may be demonstrated which is not usually thought of in connection with X rays. Three rubber balloons, suspended close together by long cords, are first charged electrically by friction. They then repel each other and stand stationary in space as at the corners of a large triangle (Plate 3, Figure 3). As soon, however, as a feeble beam of X rays is projected towards them in the manner shown in Plate 4, Figure 1, they quickly discharge and fall to their original position in contact with one another. X rays ionize air or make it conducting so that the balloons can not retain their mutually repelling charges. This is the basis of a method for measuring the intensity of beams of X rays.

SPECTRA

Another application of X rays is in the study of internal structure of crystalline chemical compounds and elements. Cathode rays, currents of negative ions in vacuum, when speeded up by high voltage, produce by their impact X rays which are characteristic of the material on which they impinge; one may say characteristic of the mass of the atom of the substance of the target. It is through this fact that the X-ray spectra of the elements considered as to wavelengths are arranged in the same order as the atomic masses in the periodic table of Mendeleeff, and by this very method the newest known element, hafnium, has been recently added to the known

metals. Referring again to our bee analogy, let a fast flying swarm strike bells so hard that they make them ring. From the sound or musical notes we guess roughly the sizes of the bells. We could thus place them in their musical series. The sound corresponds to the X rays produced when the bees are electrons of cathode rays and sound waves are ether waves. The mass of the bell is disclosed by the tone or frequency; the mass of the atom, by the same sign, is disclosed by the ether wave frequency. When a certain mineral was used as a surface for the electrons to hit, a new musical note in the ether was found. It was recorded photographically. Its place in the scale of elements had been predicted as accurately as middle C on the piano might have been predicted if it had never been heard.

With higher voltages the velocity of the cathode rays (or electrons) always increases. In the X rays thus far produced, however, the penetration or transparency is practically limited to about a quarter of an inch of lead. It is interesting to note that the similar rays from radium, the so-called gamma rays, can penetrate nearly a foot of lead. This corresponds to an exceedingly high electromotive force. Thus radium rays (gamma rays) might be made in vacuum X-ray tubes if millions of volts were applied.

ATOM LAYERS

The apparatus shown in Plate 4, Figure 2 (devised by Doctor Hull) is essentially a two-electrode vacuum tube, the tungsten filament having a little thorium in it. At a certain very high temperature this thorium rapidly diffuses to the filament surface. This thorium surface then has the peculiar power of emitting electrons a hundred thousand times as rapidly as pure tungsten at the same temperature. An ordinary lamp may be lighted in this experiment by letting this thorium electron-emission current flow through the lamp filament. The vacuum tube containing the thorium-coated tungsten also contains a little gas. When the lighted lamp is short circuited for an instant by a switch, the potential on the vacuum tube is thereby greatly increased, and this causes positive ion bombardment of the filament and thus tears the thorium all off the tungsten surface, so that very few electrons are being emitted, that is, those characteristic of pure tungsten at that temperature. Then the load (the lamp) can no longer be carried by the electron current. To repeat, the heavy positively charged gas ions under the impulse of the raised electrical potential act like a powerful sand blast and effectively clean the thorium from the tungsten, thus greatly reducing the emission current. By highly reheating the filament for a few seconds only, a fresh layer of thorium may be diffused to the surface of the filament from within the tungsten, so that then at the

previous lower temperature the load or lighting current for the lamp is carried as before by electrons emitted from the thorium surface. This is a proof of the production of a layer of thorium on the tungsten only one atom deep. The electron current from thorium on tungsten is greater than from pure tungsten, and also than pure or massive thorium, and is maximum when the single atom layer is present. This is confirmed by experiments on partial recovery of the surface and supported by thousands of successive repetitions of this experiment on one filament.

HIGH FREQUENCY

By means of an apparatus such as shown in Plate 5, Figure 1, an ordinary incandescent lamp may be lighted by being brought within a foot of a coil which is carrying a current of several million cycles. This, produced by pulsations, is about as near to wireless transmission of power as anything we now have. This high-frequency principle is also being used by Professor Northrup, of Princeton, for special electric furnaces. In these, the induced currents in the material of the crucibles or the material to be heated generate high temperature through local resistance.

LOUD SPEAKER

Plate 5, Figure 2, shows a loud speaker of unusual design. It consists of a 26-inch flat conducting disc, in a magnetic field, the vibrations of which correspond to the voice currents and reproduce the sound waves without the intervention of a horn. To operate this device, vacuum tubes are made use of as follows:

Sound waves entering a microphone cause feeble electromotive forces to be generated in the microphone. These feeble electromotive forces are applied to the grid of a pliotron and cause relatively large variations in the electric current flowing between filament and plate, which in turn are used to secure larger electromotive forces to be applied to the grid of another pliotron. By the use of several amplifying pliotrons the original feeble electric currents are multiplied several thousand times and supplied to the loud speaker which reproduces the original sounds with many times the original volume and great faithfulness of quality. To operate this pliotron amplifier requires a direct current of several hundred volts. This may be obtained by first transforming power from the ordinary alternating-current lighting circuit to a relatively high voltage, next rectifying this high-voltage alternating current by means of kenotrons, and finally smoothing out this pulsating current by means of appropriate electric circuits.

The high degree of faithfulness of reproduction realized in this loud speaker is due partly to the absence of a horn, eliminating horn resonance (one of the usual sources of distortion in a speech reproducer), and partly to the method of vibrating the diaphragm by forces which are distributed fairly uniformly over its surface, instead of acting upon it in a very limited region, as is the case in most other loud speakers. This feature eliminates rattling and ringing of the diaphragm or the production of high overtones by the diaphragm vibrating in its partial nodes.

THE USE OF RADIUM IN MEDICINE[1]

By Antoine Béclère

Member of the Académie de Médicine

Radium kills living tissue. Henri Becquerel accidentally discovered this unsuspected property. As the consequence of carrying a piece of radium in one of his pockets there developed on his chest a burn very slow in healing. This chance observation was verified by Pierre Curie. The latter deliberately placed a piece of radium on his arm. After allowing it to remain there 10 hours there was produced a painful sore which required more than four months to heal.

Pierre and Madame Curie, hoping that this as yet ill-directed force might become one of benefit, transmitted a little of the precious substance to a physician of the St. Louis Hospital. The latter carefully applied it to the killing of diseased growths of the skin. Other physicians in France, regulating and improving the technique, extended these earlier attempts to severer lesions. There thus was originated in France a new form of medical treatment. It was soon adopted and investigated in all civilized countries and increased in importance. Subsequently the curative properties of certain mineral waters and various mineral muds was traced to the radioactive properties belonging to them.

This new method of treatment was at first called radiumtherapy. Later, after other radioactive substances had been discovered, several of which proved to be of similar value, it received the designation of Curie-therapy—very appropriately, since on the other side of the Rhine a treatment making the use of X rays, discovered by the physicist Röntgen, had been called Röntgen-therapy.

Curie therapy may make use of the more general action of radioactive substances introduced in various ways in extreme dilution into the blood stream, but it much oftener uses the more specific local action resulting from the radiations from substances of which radium remains the most perfect type. This local action is found

[1] Address delivered at the Sorbonne, Dec. 26, 1923, on the occasion of the twenty-fifth anniversary of the discovery of radium. Translated by permission from Revue Scientifique, Feb. 9, 1924.

of benefit for a considerable number of diseased conditions of which the list is doubtless now incomplete. Among these maladies cancer, because of its seriousness, occupies the most important place and overshadows all others. How does the radiation from radium act upon this scourge? The knowledge of its mode of action upon cancerous tumors will enable us to understand its effectiveness in the cases of other tumors and less severe maladies.

Cancer has as yet yielded but a few of its secrets. But we now know that it is no longer to be looked upon as a fatally hereditary disease, the appearance and growth of which are so equally certain that we can only religiously or stoically resign ourselves to a certain outcome. It is, in the beginning, a local sore, a strictly and exclusively local sore, arising at a single place because of the abnormal, disordered, anarchic development of a few microscopic cells from various provocative causes. It is being studied with success in our research laboratories by means of animal experimentation.

In the first phase as a local sore it is certain that cancer is curable, perfectly curable. The necessary and sufficient condition for the cure is the suppression and complete destruction of the cancer cells already developed at the original focus and in the process of dissemination into the neighboring tissue.

For the suppression of cancerous tumors there was for a long time only one known weapon, the knife of the surgeon. We have to acknowledge that even to-day in many cases it is the best. Surgeons have cured and will yet cure cancers in great numbers. Their successes, formerly exceptional, have been multiplied since Pasteur, by his immortal discoveries, and Lister, by his applications of them, have collaborated in the development of a new surgery as audacious and beneficial in its intervention as the older surgery was timid and murderous. These successes would be even more numerous were the recourse to the surgeon not so often too tardy.

To the knife of the surgeon the researches of the physicist have now added two other weapons: First, the radiation discovered by Röntgen, and second, radium, but more especially in that complex radiation from radium made up of three different constituents designated by the first three letters of the Greek alphabet: the gamma rays.

The X and the gamma rays are of the same nature. Both possess, along with the property of passing through all bodies, the power, in proper doses, of destroying living cells. The gamma rays, besides being much more penetrating, are also more amenable to very diverse conditions of treatment. The miniature source, which the least particle of radium forms, can be inclosed in a small tube or in a fine needle of metal like unto a Lilliputian Röntgen tube. Such tubes may be distributed in greater or smaller numbers close to the skin or

may be introduced into the interior of the natural body cavities. The needles can even be made to penetrate the diseased tissues. They are minute but marvelously active and powerful sources of an invisible radiation.

In these tubes or in these needles can be sealed instead of radium the gaseous substance or "emanation" which by a process of atomic disintegration is a residium from the radiation from radium. The focus of radioactivity formed by this isolated and imprisoned emanation is not, like radium, an unchanging capital of constant revenue, but decreases and decreases at such a rate that in less than four days it loses one-half its original value. Nevertheless its use has certain advantages.

X rays and gamma rays in strong doses may totally destroy the living tissues just as do caustics; but in smaller doses they seem to make a choice, to exercise what may be called a selective action since, from among the diverse living cells of the exposed region, they kill some and leave others intact. In reality they make no selection, but the various cells of our skin, muscles, and nerves are very unequally sensitive to their destructive action. The reaction of the various cells to the same dose of the rays is as different as that of various substances—paper, cloth, woodwork, metals—immersed at the same temperature in a flame.

Those living cells which are the most sensitive to the rays are as a rule those which multiply the most rapidly. Such are generally the cancer cells and consequently they are greatly sensitive to these radiations. We may look upon the X rays and the gamma rays in effect as knives or rather invisible darts marvelously tempered and subtle, capable of riddling with wounds the whole diseased region, of piercing it without the flowing of blood, without mutilation, through intact skin, and of killing in an internal organ the cancerous cells, at the same time leaving alive the neighboring healthy tissues.

The varying chances of success of the treatment, the often insurmountable difficulties in its application, and the undeniable dangers depend essentially upon the degree of difference in the sensitiveness of the cancerous and the normal cells to the radiations. This difference, sometimes very great, is oftentimes small, and may entirely disappear. This, leaving aside other obstacles, is the great stumbling block to the successful treatment with these penetrating radiations.

Radium is therefore not a panacea, applicable to all cancers and capable of curing a cancer at any stage of its growth. Only under certain conditions it is an excellent weapon. Its applications, however, increase as the very delicate technique of its use is improved.

For quite a while the knife has given place to X rays, and for a somewhat shorter time to radium, in the treatment of superficial cancers, especially of the face and lips. It is only during the recent

years that in the case of deeper seated and more rapidly destructive cancers, much more difficult to treat, radium, aided by improved technique, has competed successfully with the knife. Such are the cancers of the tongue, of the mouth, of the throat, of the larynx, and, that most deplorable of all, cancer of the womb, which, when it attacks the mother of a family, seems a most cruel penalty of maternity, making us especially tempted to accuse nature of injustice did we not know that her inflexible laws regard neither good nor evil.

With the last-mentioned series of cancers, in cases where operations are not possible, radium, well managed, gives not only wonderful improvement, alleviation of suffering, and the prolongation of life, but also in a very goodly number of instances permanent cures. Even in cases where operations are possible, according to the most recent and convincing observations, cures by radium equal or surpass those with the knife.

Formerly the physician, in the presence of a cancer, could only ask, Is it or is it not operable? To-day he has to ask a more complex series of questions. Of the three weapons—the knife, the X rays, and radium—which compose our arsenal against cancer, which shall he prefer? Shall he employ only one or associate several? In the latter case how is it best to combine them? It is a difficult problem. Doubtless the solution several years hence will be different from what it would be now. It requires long study in institutes and special hospitals such as have been for some time established in almost all civilized countries.

In the country of the discovery of radium and Curie-therapy, painful as is the avowal, it was not until 1912 that the University of Paris and the Pasteur Institute, by common accord, decided upon the founding of an institute of radium. Its two unpretentious buildings were slowly completed during the recent war. Into their inert stones Madame Curie put the breath of life by a magnificent gift which she had agreed upon with Pierre Curie previous to his death. All the radium extracted from the ores from Bohemia by their own patience and hands became the property of the new institute to be used in the joint work of its two laboratories—the Curie Laboratory, under the direction of Madame Curie and devoted to purely scientific physical and chemical researches, and the Pasteur Laboratory, under the direction of Doctor Regaud, dedicated to biological researches and the study of the application of radium to medicine.

Soon afterwards, for the purpose of aiding and supplementing the inadequate resources of the Radium Institute, there was founded a new independent institution, the Curie Foundation, recognized as a public service in 1921, available for all general conventions and

having a special endowment. Its purpose is to promote and develop by scientific researches of all kinds on radioactive bodies and their emitted radiations, their application, principally in medicine, but more especially in the treatment of cancer. Its ambition is to discover new scientific properties and new methods of treatment for broadening the scope of Curie-therapy.

Already the Curie Foundation has an offshoot in Canada in the Radium Institute founded at the University of Montreal by the government of the Province of Quebec. This forges a new bond of affection in addition to those which already united that country with France. There is an even better evidence of this bond in the presence of Professor Gendreau, the Canadian director of this distant offspring, at the ceremonies for the twenty-fifth anniversary of the discovery of radium. It is at the Radium Institute in Paris, in the medical service connected with the Curie Foundation, the first in France of the institutions for the treatment of cancer, that Curie-therapy has recently shown its most important progress. This organization, including a dispensary already a year in service and officially inaugurated this morning by the Minister of Health, is from a practical point of view very far from being the equal of some analogous institutions of other countries. It possesses neither their wealth of radium nor their magnificent buildings. Its beds, located at the Pasteur Hospital and the Antoine Chantin medical-surgical clinic, are scattered and too small in number. It needs a special hospital, but, as an independent observer has the right to declare, nowhere can be found greater enthusiasm, ardor, and devotion to science or a more disinterested and humanitarian spirit than that which, as exemplified by their chiefs, animates all those associated in the work.

To Madame Curie.

Madame: The discovery of radioactivity and radium, while opening a new world to science, also brings a new domain for the treatment of diseases. When the Academy of Medicine unanimously elected you to its membership without any request from you, it but performed a duty in justice and in gratitude. It has the right to be proud of the glorious name of the first woman elected to its membership.

Though all minds may not be apt to understand the greatness and beauty of your conquest in the world of science, what heart is not moved with admiration and recognition before the new force with which you have enriched the possibility of lightening human misery, of triumphing for a while over suffering, disease, and death?

Wherefore your name and that of Pierre Curie will live forever with all mankind among those of its benefactors.

CLEAR FUSED QUARTZ MADE IN THE ELECTRIC FURNACE [1]

By Edward R. Berry, D. Sc.

Thomson Research Laboratory, General Electric Co.

[With 3 plates]

INTRODUCTION

It is the purpose of this article to present some of the recent results of the development of clear fused quartz and to focus attention on some of the surprising properties of this material. The art of making fused quartz dates back to 1839 when Gaudin, in France, discovered the general thermal properties of fused quartz. A number of advances have been made in the art since that date by various investigators; but most of this work has been concerned with the opaque variety of fused quartz usually made from sand. It is only during the past 23 years that the development of clear fused quartz has made very rapid progress.

It has been possible for many years to make fused quartz of a high quality in small sections and lengths by hand labor in the ordinary blast flame, using gas and oxygen. This has been done by piecing together small sections of crystal in the flame; or by adding silica powder from time to time until the piece has grown to the heating limit of the flame, an obviously slow and expensive process. From this step in the development of the art to the point where very large masses of equal quality can be made has been a long and difficult one. In the last few years the advances made by the process described in this article have been so rapid and far-reaching that there seems to be no limit now to the size of high-quality clear fused quartz which can be made, except that which may be imposed by mechanical difficulties.

METHOD OF FUSION

When it is desired to obtain fused quartz of the quality which is illustrated in this article, it is necessary to start with the very

[1] Presented at the forty-fifth meeting of the American Electrochemical Society at Philadelphia, Apr., 1924. Reprinted by permission from the General Electric Review, June, 1924.

highest quality of raw material, of which there is none better than water clear crystals. It is much more difficult to make fused quartz of this high quality from sand even if its purity exceed 99 per cent. The rock crystal used in this work is water clear and contains probably less than two-tenths of 1 per cent impurities. The surfaces are often encrusted with iron oxide and other foreign material and the crystal itself can be seen to contain clusters of small bubbles. The crystal is therefore washed in acids, and then broken up and the unsuitable pieces discarded.

There are two distinct steps in the preparation of tubes, rods, ribbons, and cane; the most important of which is the initial fusion. The clean quartz crystals, which are of various sizes, are packed as densely as possible in a graphite or carbon crucible so that during the cracking of the crystals, which is bound to occur as the temperature is raised, the parts can not separate and allow any small amount of gas which may be present to enter the many crevices and thus form bubbles. Those tightly packed crucibles are placed in a modified vacuum furnace and the temperature raised as quickly as possible to the melting point. During this fusion the pressure in the furnace is kept as low as possible. The time required for fusion will vary with the conditions and in all cases no more than 45 minutes is necessary. The energy rate of fusion is from 3 to 8 kilowatt-hours per pound of quartz, and the loss of quartz due to volatilization is negligible compared with other charges. The result of this first fusion is a clear, transparent slug containing comparatively few bubbles ranging in size from a pin point to 2 or 3 millimeters in diameter. Whether these bubbles have been formed by a gas or by silica vapor, it must be remembered that they have been formed at a temperature of about 1,800° C.; and consequently their pressure at room temperature is very small. This slug is now placed in another graphic crucible which is suspended in a vertical carbon tube furnace. A graphite piston which just fits the crucible is placed on top of the fused quartz slugs and a weight is placed on top of a plunger attached to the piston. The slugs are again brought to fusion, the bubbles are practically collapsed and by the action of the weight the quartz is extruded in the various forms, such as rods, tubes, ribbon, etc. This material is practically free from bubbles, but because of limiting dimensions it may become necessary to rework some of this, which is accomplished by the usual bench methods with an oxygen-illuminating-gas flame.

When it is desired to obtain large blocks as free from bubbles as the tubing, cane, and ribbon, another operation is necessary. As before, the quartz is fused in a vacuum furnace which, however, is also designed to withstand very high pressures. As soon as the

material is fused, the vacuum valve is closed and the pressure in the tank is brought up to some value, depending on the object in view, in less than a minute. This pressure collapses the bubbles and makes it possible to obtain very large slugs freer from bubbles than many kinds of the best optical glass.

Previous attempts to reduce the bubbles by continued heating above the melting point resulted, after a certain stage, only in excessive loss of silica by volatilization. We have fused quartz at initial pressures of 600 pounds per square inch, atmospheric pressure, and less than one-half millimeter of pressure. In the first case the mass was practically opaque; at atmospheric pressure it was considerably improved although much inferior to the present quality of quartz; and under vacuum conditions a large mass can be produced, which from the standpoint of number of bubbles is very satisfactory.

Not the least of the difficulties encountered in this development has been that in connection with the furnace equipment. The vacuum furnace in particular had to be greatly changed and enlarged with the result that we now have probably the largest vacuum furnace in daily use capable of operating at low pressures. Then, in addition to this, the furnace had to be so constructed as to withstand repeatedly on the cover a total pressure of over 1,000,000 pounds (about 600 tons), and of course as the size of the furnace increases these difficulties are multiplied. Special attention must be paid to the design of the resistor unit, to the thermal insulation, to even heat distribution, to the cooling of the terminals, and to the many other factors which present themselves in the use of these two extremes in pressure.

When the quartz crystal is heated between 500° and 600° C., it undergoes a remarkable physical change, cracking into small pieces sometimes with explosive violence. This is due to the difference of coefficient of expansion along the two axes subjecting the crystal to great strain, and to the decrepitation caused by the presence of water and liquid carbon dioxide held in vast numbers of minute cavities throughout the crystal. The only advantage therefore in using large crystals for fusing lies in the greater ease of keeping the charge free from foreign material before the different particles begin to coalesce.

Hereaus has heated crystal quartz in very small pieces, about the size of a nut, very slowly so that no cracking occurs and, consequently, no bubbles are included in the vitreous pieces. Herschkowitsch, on the other hand, has arrived at about the same result by accelerating the heating process so that a film of vitreous material is formed on the outside and prevents air from penetrating

to the center, even though cracks may develop. As a matter of fact these processes, while interesting, are subject to very sensitive control and are impractical where large masses are to be fused.

To obtain masses quite free from bubbles, it has been found best to raise the temperature rapidly to 1,400° or 1,500° C. at which point the pieces begin to coalesce. At about 1,750° C. the quartz is thoroughly fused though it is still very viscous. In fact, the viscosity is high even though the temperature be well over 2,000° C. Vaporization of fused quartz is rapid at 1,600° and at 1,750° C. the loss due to evaporation is very great. Further increase in temperature results in no great gain in fluidity.

HOMOGENEITY OF FUSED QUARTZ

The difficulties of obtaining perfectly homogeneous fused quartz free from striae, strain, bubbles, and double refraction must be apparent to anyone who has worked on this problem, and discouraging perhaps to those who have tried to buy such material. It is a little too early to state in what quantities such a product can be produced, but we have manufactured quartz of this quality which contained only two or three bubbles visible to the eye. This quality, however, has not as yet been placed on a commercial basis.

PROPERTIES AND APPLICATIONS OF CLEAR FUSED QUARTZ

The fact that for a great many purposes clear fused quartz can be used up to 1,000° C. without injury; that its coefficient of thermal expansion is so small as to make it almost negligible; and that it will transmit light rays even into the extreme ultra-violet with very little absorption, gives to it a great utility value—not only to the scientist but the manufacturer as well.

The specific gravity of clear fused quartz is 2.21. Its coefficient of thermal expansion is 58 by 10^{-8}, which is about 1/17 that of platinum and 1/34 that of copper; so small that a rod of quartz 1 meter in length will expand only about six-tenths of a millimeter for a 1,000° C. rise in temperature. The small probability of fracture under sudden changes in temperature because of this property makes it especially desirable for many uses. Furthermore, where it is used as a mirror in reflecting telescopes this very small expansion or contraction with change in temperature causes almost no distortion of the image and, consequently, much greater accuracy is made possible. This property also makes the grinding of a lens or mirror less tedious and costly, as it is not necessary to await the cooling of the shape in order to get the desired curve. It is possible to heat a tube of clear fused quartz, say five-eighths inch in diameter, to the melting point and plunge it into ice cold water without fracturing.

Its index of refraction for the D line is 1.459, and while its dispersion is higher than optical glass it is more constant because of the smaller effects due to temperature changes. If the rays which have entered are nearly parallel to a rod of quartz they are totally reflected internally, and on account of this can pass around curves, unless too sharp. This property, coupled with a very small absorption loss, makes it possible to transmit light through very great lengths of curved rod or tubing with very little loss. A rod of this fused quartz 1 meter long will emit at one end about 93 per cent of the total visible light passed into the other end. For the better grades of optical glass the highest percentage transmitted under the same conditions is not more than 65 per cent.

The ordinary run of quartz made by this process and used in the fabrication of quartz mercury-arc lamps will transmit light wave lengths as low as the 1850 Å line in the ultra violet. From the opposite end of the spectrum the heat rays also are transmitted with little loss. For example, if one end of a fused quartz rod 12 inches long is heated to incandescence, it will be found very uncomfortable to hold the finger over the other end, although one may comfortably grasp the rod a few inches from the heated zone.

Clear fused quartz is the only known material which can be obtained in quantity and which is transparent to ultra-violet rays. The medical profession is consequently utilizing this material more and more in its application of ultra-violet light for therapeutic purposes.

By the process here described it is now possible to make tubes, rod, ribbon, and cane in lengths of 30 feet and in shorter lengths of diameters up to 8 inches. Blocks have been made up to 11½ inches in diameter and 6 inches thick having comparatively few bubbles, and these widely separated, comparable in general appearance to the best quality of optical glass. Such material is suitable for prisms, lenses, and for use in instruments where the visible ray is an important factor.

Constant progress in this development is being made, and it is hoped that perfect homogeneity can be made the rule rather than the exception. It is expected that for most optical work this quality of the present material will be entirely satisfactory.

PROJECTION LENSES

Fused quartz lenses of 4½ inches diameter have been for several months very successfully operated on test in motion-picture projection machines, using currents as high as 150 amperes and where glass lenses cracked almost daily.

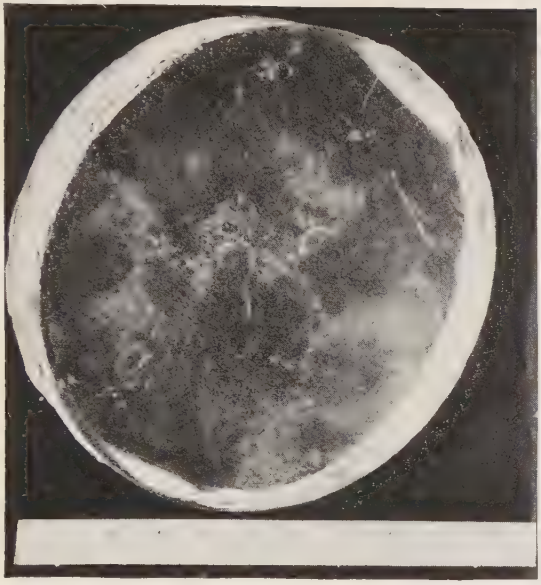
THERMOMETERS

It is well known that in the ordinary glass thermometers there is an appreciable lag in the glass, so that successive readings in a descending scale are inaccurate. To test the extent of this we have placed a standard glass thermometer and a quartz thermometer of our own construction in the same bath and raised the temperature to 515° C. and then lowered it again to 0° C. In this particular case the mercury in the glass came back to four divisions below the zero mark, whereas the mercury in the quartz returned exactly to its original calibrated mark at zero. While the capillary in the quartz tubing is not exactly uniform throughout its entire length, it is so uniform that a calibration of the tube over its whole length would eliminate any inaccuracies due to the slight nonuniformity.

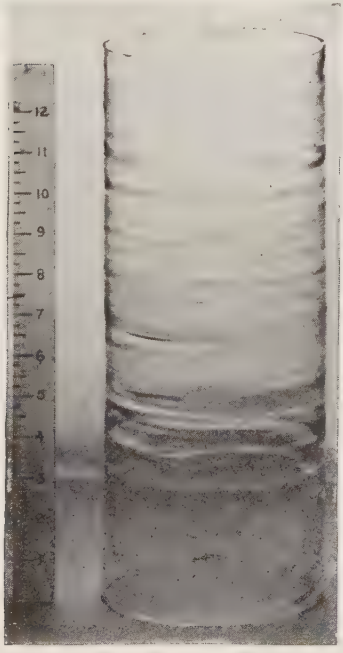
TUNING FORKS

As a standard of pitch the tuning fork is about the only appliance in use. Temperature changes affect the pitch of the hardened steel fork, however; and, what is more important, the work which has to be done in adjusting these steel forks to the desired pitch by grinding or otherwise working them, results in changes in elasticity and dimensions that cause a disturbance of the pitch note. A tuning fork of quartz is not subject to these changes to any appreciable degree.

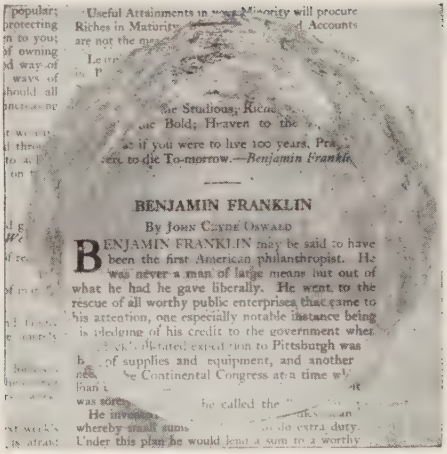
This work has all been carried on in the research laboratory of the General Electric Co. at Lynn, and in presenting this description the author wishes to express his appreciation of the efforts of Mr. L. B. Miller and Mr. P. K. Devers, who in a large measure were responsible for the good results obtained.



1. CLEAR FUSED QUARTZ DISK; 11½ INCHES DIAMETER, 2½ INCHES THICK



2. CLEAR FUSED QUARTZ TUBE; 5 INCHES DIAMETER, 13 INCHES LONG, ⅛-INCH WALL

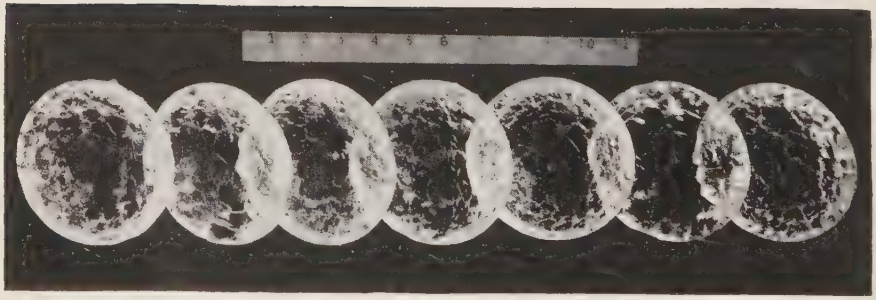


BENJAMIN FRANKLIN

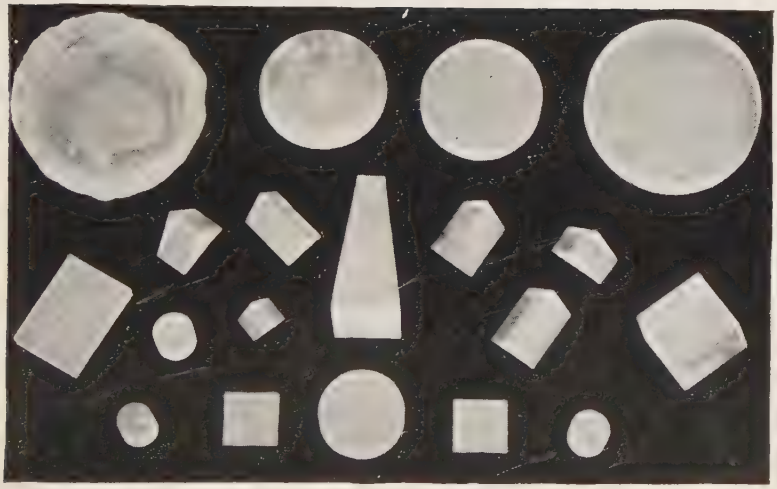
By JOHN CLYDE OSWALD

BENJAMIN FRANKLIN may be said to have been the first American philanthropist. He was never a man of large means but out of what he had he gave liberally. He went to the rescue of all worthy public enterprises that came to his attention, one especially notable instance being

1. CLEAR FUSED QUARTZ SLUG; 3 INCHES DIAMETER, 9 INCHES LONG



2. SEVEN CLEAR FUSED QUARTZ CONDENSING LENS BLANKS; 4½ INCHES DIAMETER



LENSES, PRISMS, CUBES, ETC., OF CLEAR FUSED QUARTZ

THE DRIFTING OF THE CONTINENTS[1]

By Pierre Termier

Nothing concerning the seas or their history should fail to interest you. The structure[2] we now occupy is a kind of temple erected by an enthusiastic mariner to the glory of the ocean which he had made his god; therefore, all the echoes from the mighty roar of waves past and present should converge here. Yes; even from the past, the most distant past; the dashing of waves breaking on shores which in no way resemble our own; the roll of waters which divide an instant to engulph some great island, as fabulous Atlantis, or some bit of continent, and close again with a lazy indifference over so many swallowed-up treasures; the roar of the terrible tidal wave, the *tsunamis* of our Japanese brothers, which has caused agitation, undulation and trembling from the depths of the sea, and which has rushed to the assault of the continental domain, overturning all, leveling all, mowing down the terrestrial life and its work of a day; subterranean sounds from unfathomable depths, scarcely to be perceived, while listening to the importunate murmur of living beings and flying meteors, and which are the sighs of the earth in travail, of the earth incessantly deformed, increasing or diminishing its oceanic areas, folding the bottom of its seas, elevating it, after having folded it, then raising it above the waters as if to menace the heavens, and sometimes, after having thus elevated it, dragging it back into the marine depths lower than before. Sound, indeed, who knows? A sound almost imperceptible, so slight, so little different from silence itself, of continents *en marche*, which slowly, oh very slowly, as great pontoons floating on the calm waters of a port, or as giant icebergs borne by the polar currents, are drifting toward the Equator.

This is the very question we are going to consider this evening: Are the continents absolutely fixed; the one in relation to the others and all in relation to the profound depths? Are they really terra firma, as the sailors say when, worn out by the rolling and pitching from the depths of a monsoon, they dream of the old iron ring on the sun-flooded quay? Are the outlines of the seas on the surface of the planet invariable?

Let us suppose an observer without sense of time, indifferent to its duration, for whom a thousand years are as a day, were placed beyond the earth, for example, at the distance of the moon, contem-

[1] Translated by permission from Revue Scientifique, May 10, 1924.

[2] Institut océanographique of Paris, founded by Prince Albert I of Monaco.

plating the full earth, "round and shining" in the midst of black space. Would this observer always have under his eyes an orbit of the same aspect, as a child learning geography turns in his hands one of those globes prepared for teaching and finds again and again before him the same contours and the same colors?

Would this observer always see the same America extending from north to south, gradually contracting from top to bottom, divided in two parts by a large indentation, the lesser being strongly refracted toward the east? Would he always see the same mass—Europe, Asia, the Eurasia of Edward Suess, extending parallel to the Equator and broken by long and high mountain chains; then, separated from Eurasia by a zone of indentations, the Mediterranean, the Red Sea, the seas of the Malay Archipelago with their numerous islands, two other great masses, Africa and Australia, which resemble each other in their massive form and simple contour with their blunt southern terminations, Australia having Tasmania, a blunt point to the south, and both refracted toward the east in their southern portions after the manner of America? Would he always see between these two great continental systems the same oceans, stretching out infinitely toward the south, narrowed and almost closed toward the north? Would there be the same islands—islands on the eastern side of Asia, arranged in garlands parallel to the curve of the coast; islands of Oceania in long archipelagoes which have the form of arcs and which seem from afar like light strokes of the brush on the immense and monotonous painting of the Pacific? The Sunda Islands extending along Asia, first in a regular and orderly fashion and then mixed as in a kind of whirlpool in the Celebes and the Molucca Seas, finally becoming united at the north of New Guinea, with one of the insular arcs of Oceania; the Antilles forming a semicircle open to the west; the islands of the extreme south of South America presenting also this arrangement, a semicircle open to the west, a semicircle whose diameter, extending from north to south, reaches from Cape Horn to the South Pole? Has there been for a million years the same geography? Or, indeed, if our observer fell asleep for a moment, if he closed his eyes for some dozens of millions of years, would he have been surprised on awakening to find before his eyes a new and rejuvenated earth, continents with other outlines, different mountains, seas which he did not know, conditions in short which give this suppositional being the sensation of having been inattentive, a feeling of progress, of change, in a word, a sense of time which was before lacking in him?

All geologists, without hesitation, would respond to a question put in these general terms, that the face of the earth is not unchangeable. All teach that the outlines of the seas vary; that the continents are terra firma only in appearance; that they are rooted perhaps, but

that their roots, flexible and elastic, permit them near the surface to draw nearer to each other; that the oceanic space included between two continents can therefore contract much, for example, from a half to two-thirds of its original width, and then this space, formerly the sea, becomes a line of folds, a mountain chain which will dominate superbly the continents thus brought nearer together. Geologists differ only in their interpretation of the extent of these phenomena and in the manner of accounting for them.

Yes; geography is variable. We have known that for a long time. It varies at first a little, very little, I mean to say very slowly, under the action of two powerful leveling agencies—erosion and sedimentation, which tend to equalize the surface of the earth and to establish there the universal ocean, the Panthalassé of Edward Suess—erosion which disaggregates, wears away, dissolves, rounds off, modifies the mountains and very slowly transforms them into a peneplain; sedimentation which fills the lake basins and tends to diminish the depth of the seas. But geography changes especially by the peculiar movements of the planet which I call its convulsions. These movements are of two kinds, vertical and tangential. The vertical movements displace the shore lines, cause the sea to advance on the continental domain or recede, rejuvenate the monotonous peneplains and worn-down mountains, deeply embank the rivers; elevate or depress the high chains and thus in turn increase and lengthen or diminish the glaciers; raise new mountains or plunge beneath the sea portions of continents, vast islands, or entire formations of a formerly majestic mountain chain. They change the conditions of life and of sedimentation at the bottom of the sea by changing the depth and the remoteness of the shore.

These vertical movements are some thousands of meters in extent. They have the singular double character of being oscillatory and at any time counterbalancing each other so nearly that the mean level of the seas does not greatly change. While certain points of the surface rise some thousands of meters and others sink simultaneously a comparable amount, the mean level of the sea in comparison with the supposedly fixed mean level of the continents varies only a few hundred meters.

The tangential movements are those which wrinkle the surface of the earth, transforming an entire section of the surface into a system of folds, which needs only elevation to become a chain of mountains. The extent of the tangential movements is indeed far greater than that of the vertical; for a particular chain it is some hundreds of kilometers, if indeed it does not attain to a thousand. The chain of the Alps, for example, whose width, to-day, scarcely exceeds 250 kilometers, resulting from the contraction of an elongated zone

for a long while occupied by the sea, was formerly at least 800 kilometers wide, perhaps a thousand. The southern margin of this zone has approached the northern margin, and the sediments accumulated on the bottom of this elongated sea have been folded and even refolded upon each other. If, instead of the Alps, we consider the entire system of the great chains of central Asia which is actually 3,000 kilometers from north to south, we are led to conclude that the transverse sea roughly parallel to the Equator, was formerly at the very least 6,000 kilometers in width for, in this sea which the geologists call Tethys were deposited the sediments which constitute the major part of these chains. It was a sort of transverse Atlantic; it has gradually narrowed by the contraction of its margins, a contraction which has proceeded without doubt by successive abrupt movements, whose total extent embraced eight or nine of our geological periods, that is to say several hundreds of millions of years. Such is the common teaching of geologists on the deformation of the surface of the earth; and you see that they all play a large part in the variations of geography and in the mobility of the lithosphere.

But very recently, in 1912, a German geophysicist, Alfred Wegener, conceived the idea of a very much greater mobility. He uprooted the continents and compared them to pontoons floating to a port, of which I was just speaking, or, better still, to those icebergs which each spring are born by the breaking up of the polar ice flow and, carried away by the polar currents, pass toward the temperate regions of the ocean, a white flotilla dreaded by navigators. These mountains of ice drift with a speed varying slightly according to their form and dimensions, and the inequality of their progress soon exaggerates the distance which separates them. The same thing occurs with the continents. Here, for example, is the Europe-Asia-Africa mass; it was united formerly to the American mass, and there can still be seen on both sides of the Atlantic an undeniable similarity in the outline of the shores. Between these masses, which were formerly one, a fissure opened which gradually enlarged, because, in the general drifting toward the west, the American mass moved more rapidly than ours; and this fissure, to-day from 2,000 to 6,000 kilometers in width, is the Atlantic. Wegener thinks America broke away from us; perhaps we shall never overtake her.

The chains of islands bear witness to the movement of the continents. The islands are comparable to the small icebergs which break off on the edges from the great mountains of ice and remain behind, being more retarded in the intervening waters on account of their small sizes. The islands form a group of stragglers behind a continent which advances. Consider the insular arcs of eastern Asia,

the Aleutian Islands, the peninsula of Kamchatka, Kurile, Sakhalin, Japan, Liu-Kiu, Formosa, Philippines, and Borneo; are not these fragments of the Asiatic coast detached nearly simultaneously and showing, by their arrangement in garlands parallel to the outlines of the shores, that they formerly belonged to them? And the chain Sumatra, Java, Sumbawa, Flores, Timor, what is it, except a truncated extension of this tail of Asia, the Malay Peninsula? The sections of the Asiatic tail follow the general movement of Asia but with a slight retardation. What are the Antilles if not fragments large and small of Central America left behind, the little ones more retarded than the large ones and forming a flotilla whose center advances less rapidly than its wings and which incurves thus in form of a semicircle open to the west? And what do we see at the southern extremity of South America? The point of the continent twisted toward the east, twisted at right angles, then at Cape Horn, and in Staten Island abruptly broken; but a little further to the east there are the remains of this point—South Georgia, South Shetland, South Orkney, Sandwich Group, all one series of wreckage, outlining another incurved flotilla whose left wing almost touches the point of the Antarctic, which point twists toward the east, as does the American point which faces it across Drake Strait. Does not this disposition in semicircles of the two points and of the archipelagoes cause one to vision the rupture of an old bridge which should have joined the Antarctic to South America and which, being without doubt too thin to resist the thrust of the marine depths opposed to its drifting toward the west, would have twisted its two abutments, and not being able to rest entirely coherent after twisting, would have broken in disjointed groups of scattered masses?

Finally, let us consider Australia. Above is New Guinea, which seems to be only a detached portion; above and to the right of New Guinea a whole chain of islands, which curve toward the south parallel to the Australian coast including New Caledonia and farther New Zealand. Does it not seem to you that this chain of islands joins from the north of New Guinea to that of the Malay Archipelago which I called, a minute ago, the truncated tail of Asia? The joining takes place in the region of the Molluca and the Celebes, where the archipelagoes twist around confusedly. But would not this twisting be due to the advance from south to north of the enormous mass of New Guinea-Australia? Would not these sections of the Asiatic tail formerly extending toward the southeast, as Sumatra, have been deviated toward the north by the drifting of Australia? Their flotilla, formerly regular as a well-conducted squadron, would it not have been dislocated and dispersed by the prow of New Guinea advancing and does not this flotilla, extending further the direction of its route and simply bent by the moving

obstacle, again outline on the Pacific the regular arc ending at New Zealand? To these questions of Wegener I confess I have often been tempted to respond in the affirmative.

But Wegener goes further still, so far that one hesitates to follow him. He does not hesitate to attribute to the resistance of the deep fluid interior on which the continents float and in the interior of which they are plunged, of attributing, I say, to this resistance, the tangential movements which have folded the lithosphere and fashioned the mountain chains. The long chain which dominates the western shore of America, the Rocky Mountains and the Andes, would result, according to him, in the marginal folding of the border which serves as prow to the immense ship while it drifts toward the west. Perhaps it might be thus for any long chain; it would indicate the direction and, on careful consideration, the trend of the ancient continental drift. Australia would formerly have moved toward the east before advancing toward the North; Africa would have had, at a very remote epoch, at the end of the Primary, a rapid movement of drifting toward the south, to which the mountain chain of the Cape bears witness.

Such a theory has the possibility of being extremely convenient, an advantage which is not without grave danger, the danger of making superficial minds believe that enigmas are solved when they are simply displaced and replaced by those more general and much more irresolvable. Yes, it may seem very convenient to unite two continents or to separate them at will; to join them to explain the migration of the fauna and flora from one to the other, or the extension from one to another of some line of structure, for example, a chain of mountains; then separate them to explain on another occasion the dissimilarity of biological conditions that one observes there, or the difference which manifests itself in the geological history of two continents during an indefinite period of time. It is also very convenient to admit, with regard to the continents, that the terrestrial poles could shift. This, by a stroke of the pen, does away with all difficulty relating to the distribution of climate during the different geological periods. And if you are adverse to the idea that the axis of the earth may be movable, you will be told that this mobility is not all necessary; it is sufficient, the poles remaining fixed, to have the continents glide around the globe. By means of this gliding you may construct at any moment the geography which seems to you most in accordance with the image which you have of the face of the earth in keeping with the geological data at the same moment of its duration.

Here is a characteristic example of this extraordinary and very seductive convenience. Toward the end of the Carboniferous period, when coal was being formed in many parts of the globe by the

accumulation of vegetable remains in the lakes, ponds, bogs, and lagoons, geological observation reveals to us that there were wide differences between two vast regions of the earth's surface—biological differences and climatic differences. The first region embraced central and southern Europe, central Asia, extending to the south as far as the northern border of Hindustan, and then North America between the Great Lakes and Texas. In this region the immense coal basins had just been filled and the others were still on the point of filling up; the vegetation was incredibly luxuriant; never at any other point of geological history had the vegetable kingdom known such exuberance. This vegetation was everywhere as varied as possible, considering the state of development which the world of plants had then attained, the plants of the American coal measures, for example, being the same as the Franco-Belgian or the Chinese. From the exuberance of the flora and also from the character of the fauna one is led to believe that everywhere the region in question enjoyed a very warm climate; nowhere so far has there been found the least manifestation of glaciation. A second region presented itself, entirely different, separated from the first by a transverse sea which extended from the actual position of Central America and that of the islands of the Malay Archipelago, passing by the north of Africa and the north of Hindustan, thus forming a belt halfway around the earth. The separation brought about by this sea was an effectual one, for in the region of which I now speak, and which extends south of this sea, grew a flora plainly and almost totally different from that of the first region. The second flora was much less luxuriant, much less varied; it offered to a very high degree the characteristics of monotony and poverty which belong to a country relatively cold. A plant group dominated there, the species *Glossopteris*, which is a fossil species of Fougere (fern), and one often speaks of the Glossopteris flora, Glossopteris region, Glossopteris period, to designate by a word those biological conditions, the region where they dominated, and the very long epoch during which they lasted. The *Glossopteris flora* was the same, or nearly the same, in the whole continental domain, which extended to the south of the transverse sea. It was very vast, since it included Hindustan, Australia, Tasmania, Transvaal, the whole great African area north of Transvaal, Brazil, and in the south extended as far as the distant Falkland Archipelago. And, a very important fact, over the enormous spaces of this continental domain there had been during the time of the Glossopteris flora manifestations of glaciation. Almost everywhere the first coal measures rest on a very extensive moraine; at certain points one ascertains the superposition of many moraines separated by coal measures. Thus the glaciers have advanced on the Glossopteris region as much in Hindu-

stan as in Tasmania, as much in the Falklands as in the Transvaal; and this glacial episode, many times repeated, seems to have been as important and as general, even if not more so, than the great glacial invasions of the north during the quarternary period.

All this is very difficult to explain and very embarrassing to the geologist. One has dreamed of the displacement of the poles and attempted to place the South Pole in the Indian Ocean not very far from the Cape of Good Hope to account for the cold climate and the glacial invasions. But then two obstacles are encountered: First, as there is a difference of nearly 70° of latitude between the Cape of Good Hope and the northern border of Hindustan, at the foot of the Himalayas, it is necessary to carry the glaciers which came from the South Pole even within 20° of the Equator; further, the North Pole, antipode of the South Pole, would then fall in Mexico or in the Rocky Mountains, in a country where the deposits of the Upper Carboniferous are of calcereous Fusulina—that is to say, sediments formed in a warm, not polar, sea.

With the theory of Wegener everything arranges itself, and there is no more difficulty. Let us suppose that in the Carboniferous the African mass may be joined to the Brazil, that the Hindustan may even be joined to the African mass, the southern point of Hindustan coming to attach itself to the east coast of Madagascar, and Madagascar being itself attached to the African coast; that Australia may come to aggregate itself also to this mass by joining its west coast to the east coast of Hindustan. There is thus a great southern continental mass, which a transverse sea, the Tethys, separates from another, the northern mass thus uniting again North America to the north of Eurasia. By simply gliding let us displace on the globe the two masses and Tethys, with regard to the supposedly fixed axis of the earth. Let us arrest this movement in such a manner that the South Pole may be in what is to-day the Indian Ocean, not far from the region where we have made Australia, Hindustan, Madagascar, and Africa come together; all this region becomes polar antarctic, and it is therefore quite natural that the climate there should be rigorous and promote glacial invasions. At the same time the North Pole falls no longer in the Rocky Mountains, but in the open Pacific, on account of the union of North America and of Eurasia—that is to say, in a region whose geographic and geologic conditions during the Carboniferous period are totally unknown to us. Finally, and this is the most seductive part of the hypothesis, the coal basins of the Tethys and of the northern border of the Tethys, those of China, southern Siberia, southern Russia, Poland, Germany, Belgium, France, Great Britain, Canada, and the United States are all either on the Equator or within less than 30° of north latitude. One, then, can understand the warm climate which reigns

everywhere with the same exuberance and variety of vegetation which covers them. It is admirable; but in order not to be misled it is necessary to remember what I said a moment ago of the danger of these very convenient hypotheses which make appeal to occult forces, perhaps inexistent, and which afford us the formidable power of disposing at will of the continents and seas.

Such is Wegener's theory of the drifting of the continents, with its undeniable attractions and deceptive power, probably misleading. It was received with very great enthusiasm, at first, especially among geophysicists and in Germany. The inconsistency came later. It is a curious thing that, in spite of the latitude which this theory gives to geologists, there are those amongst them who have been unwilling to accept it and are the ones who have raised the strongest objections. Let us consider the matter a little more closely.

What could be this fluid magma on which the continents float and in which their bases are immersed? According to Wegener, it is a bath of melted rock having almost the composition of the heaviest lavas emitted by our volcanoes. You know that lavas vary from one volcano to another and sometimes even in the same volcano from one eruption to another. There is a whole gamut of lavas, the lightest of which, richest in silica and oxygen, when solidified are of the lightest color and have very nearly the chemical composition of granite, while the heaviest, the most basic, charged with magnesia and iron, have a much darker color and are even at times entirely black; these are called basalts. From one extremity to the other of this gamut the density of the lava, supposedly solidified and completely crystallized, varies in round numbers from 2.8 to 3. It is a very remarkable fact that the gamut of lavas has not changed since the most distant geological epochs of which we have any knowledge. Even in pre-Cambrian times, probably already when life began, there were volcanoes which ejected lavas in every way resembling those of the Tertiary volcanoes, some that are called rhyolites, having the chemical composition of granite, others that were basalts, identical with our basalts, and a series of others of intermediate composition. Hence the idea that there is all around our globe, under the solid crust, or lithosphere, a liquid spherical zone, or pyrosphere, from which the volcanoes have always been and still are supplied; that, since the beginning of geological time, the mean limit of the lithosphere and the pyrosphere have not sensibly varied; that, periodically, but with a periodicity unknown, on a vertical scale this limit rises or descends, but without exceeding a maximum value, neither does it descend below the minimum value of its distance to the center of the globe. On the other hand, all the geophysical data make us believe that, in the interior of the earth the elements are classed, at least approximately, in the order

of their increasing density from the periphery to the center. The zone next to the surface is formed of light rocks such as granite, rich in silica, oxygen, and aluminium; it is the *salique* zone or the *sal* (Si, Al) of Edward Suess. Lower, silica, oxygen, and aluminium diminish, while calcium, iron, and magnesia increase; it is the zone *simique* or the *sima* (Si, Mg) of Edward Suess. Lower still, there is little but iron, with some other metals, such as nickel; Edward Suess called this zone *nifique* or the *nifé* (Ni, Fe). The probability is that the series of the mingling of the elements may be continuous, and that there may be no precise demarcation between *sal* and *sima*, between *sima* and *nifé*. The same holds for the physical conditions. Under the solid lithosphere there is the liquid pyrosphere; under the latter, what is the physical condition of the deep interior which becomes little by little nifique in its composition? Is it a solid? Is it a gas? We do not know, and we content ourselves with calling this interior the *barysphere*. The probability is that there may be a continuous gradation from the solid of the lithosphere to the liquid of the pyrosphere, and also from the liquid of the pyrosphere to the unknown physical condition which is that of the barysphere. It is not, however, absolutely impossible that there may be some discontinuities, especially in the series of the physical conditions; but, if such, they elude us, of course, at every conjecture.

To uproot the continents and render them mobile, Wegener supposes the existence of such discontinuities; he supposes that the separation of the *sal* and *sima* is clearly marked. The *sal* forms the continents; they are entirely solid. The *sima* under them is entirely liquid, without the viscous transition between liquid and solid; under the oceans there is only *sima*, at first a very thin pellicle of solidified *sima*, then, under that, the general bath of molten *sima*. Wegener admits that the *sal*, of which the continents are formed, is a solid having a mean density 2.8; he admits, on the other hand, that the liquid *sima* has a mean density of 2.9. A piece of continent, a fragment of *sal*, floating on a simique bath, will be deeply submerged in it, after the manner of mountains of ice which float on the sea, whose submerged depth is very much greater than their visible height; for the fragment of continent, the submerged depth will be about nineteen times the emerged height. As there is a difference of nearly 5 kilometers between the mean distance to the center of the earth of the continental domain and the submarine domain constituted by the bottom of the oceans, it is necessary, says Wegener, that the continents be submerged some 95 kilometers in the liquid *sima*.

Can you conceive of this strange earth? Around her a spherical liquid envelope, formed of lava, which if it became solidified would be analogous to basalt; this lava is not only liquid, but very mobile,

almost like water; on the spherical liquid envelope are placed the oceans, separated from the molten bath by a very thin pellicle of basalt, just sufficient to assure the separation and not to be broken at any moment under the action of the tides; in the remainder of the bath are submerged the continents, composed of solid *sal*, immersed as much as 95 kilometers deeper than the suboceanic pellicle. Rising above this pellicle there are only some kilometers of hard rocks which dominate for some hundreds of meters the level of the seas.

And here is that which shakes and displaces all. A continent advances, like an enormous ship. The simique pellicle which makes the bottom of the oceans gives way before it, powerless to imprison it. As the steam in the polar seas breaks victoriously in the morning under its beam the young ice formed during the night, which tries to make it captive, the continent advances, under the power of one knows not what, an irresistible force. But the reaction of the surrounding *sima* restrains it; restrains it so much that it folds marginally this margin which descends a hundred kilometers below the surface, and this folding of the profound depths, extends as far as the upper limit of the vast mass, and causes there an assemblage of folds, a chain of mountains. Again, in the couse of the drifting, the mass breaks by a narrow fissure, the underlying *sima* gushes forth, some basaltic volcanoes open and flame; then the fissure enlarges, the sea penetrates it; this will form later, perhaps, a new ocean; or else it may only be a momentary breaking of the two borders which will be brought together again and join themselves anew. In the meantime, behind the advancing continent, some islands originate from the crumbling of its long and fragile stern they will be retarded in the simique pellicle continually reforming around it; the flotillas of islands, which will follow from afar, with the gentle undulations of a scarf agitated by the wind, or the brusque unexpected arrival of another immense vessel, of another continent advancing, will throw it in confusion and cause it to whirl tumultuously. Confess that the vision is magnificent. I see it often before my eyes and never without inward enjoyment, as if I were seeing a very beautiful work of art.

If it is true that the *sima* forms the very bottom of the oceans, while under the continents it is held at a much greater depth, one should find that gravity is greater in the oceanic domain than in the continental; in this latter domain it should be less in proportion as the country is more mountainous for the Archimedian equilibrium, the isostasy, as they say, demands that the more elevated the surface of the continent is the more deeply it descends in the *sima*. This is in fact what one ascertains from the laws of gravity. The adherents of the theory argue from that; but they would be wrong to believe that the argument is decisive. One can, indeed, explain the diminu-

tion of gravity in mountainous countries by noting that in the mountains and under them the parts of the lithosphere nearest to the surface, and hence the lightest, are folded and heaped on themselves and thus they have driven back toward the depths the denser lower zones. One can also contend that the differences of gravity are original; that the lithosphere is not and never has been homogeneous; that the oceans installed themselves, from the beginning, over the densest regions, which correspond to the depressions of the surface; that the continents are the less dense regions; and that this primitive distribution of relief has hardly changed up to our time. The consideration of the inequalities of gravity does not solve, then, the question of whether the continents can drift widely or whether they have been anchored for a long while; since on the earth, which had just cooled, the seas were formed and circumscribed.

In the theory of Wegener as the author presents it to us, there are numerous and strong improbabilities. The whole is seductive; many of the details are startling. I do not speak of the fundamental conception, little probable, little satisfying, of the existence of the physical and chemical discontinuities in the interior of the earth. But who could believe, for example, in the formation of mountain chains by the reaction of the liquid *sima* on the advancing continent? If the *sima* is capable of opposing such a resistance to the movement of the floating mass, how is it that this mass is not held by the *sima* and how can it move? In the hypothesis of mobility, what becomes of the débris of the solid simique pellicle which forms the bottom of the ocean? Should it not accumulate in a thick fold of dark heavy rocks under the prow of the great ship? But nothing resembling it appears. How can the deep foldings of the solid continental *sal*, under the thrust of the liquid *sima*, transform itself in rising toward the surface and form these folds and beds that we see in our mountains and which suggest the idea of superficial wrinkles much more than that of a very deep seated disturbance propagated in a vertical direction.

Supposing that one could accept Wegener's orogenic hypothesis for the Cordilleras of western America, or south Africa, or eastern Australia, it would be necessary to find another to explain the Alps, the Apenines, the Caucasus, the great chains of Central Asia. This is indeed what Wegener tries to do; but who is the tectonician who would consent to accepting two entirely different orogeneses, one for the Andean pile and those resembling it, another for the immense transverse chains which are the highest summits of our world and which have replaced the ancient Tethys? How believe that under the oceans the basalt magma may have a density of 2.9 and that it may still have the same density under the continents at a very much greater depth, 95 kilometers greater?

Note that 2.9, or rather 3, is the density of *solid* and *crystallized* basalt at the surface of the globe; the density at this same surface of fluid basalt, of flowing basaltic lava, is indeed less; and the density of this basaltic fluid certainly varies with the pressure to an extent unknown. So that the calculation of the ratio of the plunged and submerged depths of *sal* seems a little illusory. How to admit finally that in a bath of *sima* of such mobility, in a bath where the great blocks of *sal* float and drift, the tides determined by solar and lunar attraction may not be sufficiently energetic to break each day the thin pellicle which separates the molten *sima* from the oceanic waters? For it is indeed necessary that this pellicle be very thin, otherwise it would imprison forever the continents it incloses.

But in the matter of geological hypothesis the improbabilities do not count. They do not prove that a theory may be radically false; they simply show that it needs to be ameliorated, corrected, accurately stated. If one does not accept the theory of Wegener, it is not because there are others fully satisfactory. Thus far none has been proposed which does not also show some striking improbabilities. Between these theories, which displace the enigmas without solving them, we choose according to our tastes and temperaments, some finding acceptable those which others declare absurd, unless we should prefer to take refuge in a kind of scientific agnosticism. In truth there are geological phenomena themselves astonishing and improbable, of the existence of which one is entirely certain. How, henceforth, expect to explain them? We know that the lithosphere moves, that its movements have periodic returns, that certain of them are oscillatory; we also know, or think we do, the extent of their amplitude. That is all. Of the profound causes of this mobility, of the manner in which the movements begin, progress, and cease, we know nothing.

To ameliorate Wegener's theory and render it lasting, to do away with the gross improbabilities of which I have spoken, we can trust to the geo-physicists. They will conceive by new hypotheses other details of the "machine," as Pascal remarks, details which perhaps will not be more correct than the first and which, in any case, will not be more possible of verification.

Some days ago, in a communication which I had the pleasure of presenting to the Academy of Sciences, my excellent friend, Emile Belot, with whose original and bold ideas you are acquainted and whose cosmogonic theory has interested Henri Poincaré himself, recalled that, long before Wegener, he had attempted to explain in an entirely different manner the genesis of the continents and the oceans; and he showed how his own theory accounted for the original grouping of the continents in a single mass, a grouping

which Wegener supposes but does not explain, and how this same theory accounted for the displacement of the continental masses, which one searches for in vain in the German theory. But there are many hypotheses in the theory of Emile Belot; there is, above all, the hypothesis of the transport of the earth at an enormous speed to the midst of a tranquil nebula, "transport en projectile," which the author uses with admirable ingenuity. This furnished him with an exterior force, the resistance from the nebula, which he called "the wind of the nebula." As the earth, in the hypothesis of Belot, travels in a direction parallel to its axis, the North Pole forward, the two poles are very unequally swept by this nebula wind. When the deluge of the primoidial waters fall on the slightly cooled earth it will take the form of frightful squalls, generators of the most frightful torrents, capable of sculpturing the soft crust; these torrents accumulate the *sal* at the North Pole and, on the other hand, denude the *sima* at the South Pole; they hollow out profoundly the bed of the oceans and will give to the continents their definite pointed form toward the south. It is further, the wind of the nebula which, by retarding the terrestrial rotation, very unequally, according to the latitude and very differently in the two hemispheres, furnished Emile Belot an explanation of the twisting of the continents toward the east and, in a general way, that of the tangential displacements parallel to the Equator. As to the tangential displacements parallel to the meridians, the author explains them by means of a new hypothesis—the hypothesis of the periodic fall on the earth of many satellites in annular form, analogous to the rings of Saturn. Thus ingeniously everything is accounted for and it is surely a very amusing effort, but it can not be proved.

Very recently, also, an English scientist, J. Joly, gave his interpretation of the theory of the drifting of the continents, making appeal to radioactivity to supplement the German thesis, thus making it capable of explaining a greater number of phenomena. Joly admits, as does Wegener, the existence of a spherical envelope of basalt all around the globe, under the continents, and under the oceans; but he reminds us that most of the rocks that we know are radioactive. The basalt of the profound depths is therefore radioactive; it consequently constitutes a practically indefinite source of heat. One might think that the emanations from this source would be constant. But Joly in his hypothesis makes the flow variable and periodic. The release of heat, through the disintegration of the radioelements, is by paroxysms, separated by long periods of inaction. Hence the deplacement of the isogeothermal regions in the interior of the earth; they rise or fall; and the sphere of basalt, which supports the continents and oceans, is sometimes formed of solid basalt, sometimes becoming liquefied very near the surface and

even transformed—another hypothesis—into an extremely mobile liquid. Let us consider the passage from the solid to the liquid state, by the rise of the isogeothermes; it is accompanied by great expansions of the basalt and a strong diminution of its density. The bottom of the seas are elevated; consequently as the mean level of the seas rise also, the continents would follow this centrifugal movement; but they are retarded because, being immersed in a liquid the density of which diminishes, they tend to sink deeper. The result is an encroachment of the sea on the continent, which the geologists call a transgression or a positive vertical movement. Some millions of years pass; the radioactivity becomes quiescent; all the phenomena are reversed; the sea recedes; it is a retrogression, a vertical negative movement. At will we shall thus make marine transgressions and retrogressions, constant or intermittent, and we shall give them any extent that we wish; we could as well make them universal. In this way we shall account for the vertical oscillatory movements.

To explain the tangential movement and the possible drifting of the continents, Joly invokes the tides. In the periods "of revolution," as he calls them, when the basaltic envelope is become molten and very liquid, very mobile, nearly to the surface, this liquid, mobile and yet very heavy, undergoes, from the attraction of the sun and the moon, very strong tidal movements, much stronger, indeed, than those of the sea, tides which tend to retard the speed of rotation about the axis of the superficial terrestrial zones. This retardation, which decreases quickly in depth on account of the increasing viscosity—another hypothesis—is very marked in the parts of the liquid pyrosphere which are immediately beneath the bottom of the oceans; naturally so much the more marked the nearer the Equator. Thus originates the tangential force, proceeding from east to west, in a sense inverse to the rotation, the tangential force of the molten magma on the submerged parts of the continental masses. Thus originates the drifting of the continents, and, as the continents are very fragile—another hypothesis—they break and fold easily and in this manner the mountain chains are formed. To those who would object that the theory thus presented explains neither the transverse chains parallel to the Equator, as the Alps and the Himalayas, nor the chains near the poles, I imagine that Joly would respond that the poles in the course of time have changed places in relation to the great continental masses, and that the Tethys, on whose site to-day the Himalayas and the Alps run parallel to the Equator, was perhaps formerly an ocean extending from north to south, as our Atlantic. The speaker would answer that the chains which actually extended along the shores of the Pacific were very nearly of the same age as the Alpine chain and the Himalayas, and that the difficulty of explaining the simultaneous origin of all the

chains still existed. I do not know what Joly would reply. I know only that he would answer and that the discussion would be endless. "Dieu a livré le monde aux disputes des hommes." (God has delivered the world to the disputes of men.)

For my part, that which keeps me from accepting Wegener's theory and from admitting the great mobility, the total mobility of the continents, is that I believe permanence to be a fact, permanence on the face of an earth incessantly changing, of some profound characteristic features, always recognizable for hundreds of millions of years, at least since the beginning of the Silurian period. These features are: First, the existence of a very special Pacific domain around which extends a zone equally very special, that I call the zone Circumpacific; and, in the second place, the existence of a transverse domain forming a half girdle of the earth, uniting at its two extremities the transverse domain to the Circumpacific, a domain for a long time occupied by the sea—which was the Tethys—but to-day occupied by two immense chains of mountains of very different ages, nevertheless very nearly parallel and even, sometimes superimposed over large areas. Yes, as far as I look into the past I see these two features, permanent or nearly permanent. This large half girdle, sometimes marine, sometimes folded and mountainous, and what magnificent mountains! extending from the Antilles to the islands of the Malay Archipelago, and, completing the half girdle with a high and large buckle, which puts the finishing touch to the encircling of the earth, this Circumpacific zone made of the combination of the juxtaposition of long, uplifted folds which are the mountains and of the long, depressed folds which are the submarine valleys, this zone perpetually mobile, where volcanoes continually become active or quiescent, and which to-day underlines this volcanic belt, the belt of fire of the Pacific. I see on the face of the earth many changes, some deformations, but I am struck less by the mobility than by the permanence. It seems to me—oh! I know that I may be mistaken—but it seems to me evident and certain that the Pacific has always been in the same place and that only its borders, its depths, and the number and outline of its islands have varied, and I hold also as almost evident, and almost certain, that, if the transverse half girdle is very greatly reduced in its width, perhaps one-half, perhaps two-thirds, by the drawing together of the continents which it separates, it has not varied much in its length. It is that indeed, more than this or that improbability of the explanations of Wegener, or this or that flat denial given by geological observation to the former pretended welding of the two continental borders which face each other; it is that which makes me differ from the German theory, in spite of its undeniable charm and its real beauty.

"And yet it does move," responded Galileo to the philosophers of his time, who declared it impossible that the earth turned; and still it turns. I imagine that such is the last response of Wegener to objections and to criticisms. What matters—is not to know how and why the continents drift—one will probably never know that—it is to know whether they have drifted greatly in the past, whether they are still drifting at the present time, and, consequently, whether we can predict that they will drift again to-morrow.

Of their great drifting in the past, further than the shifting of the continental masses which it is necessary to admit in order to explain the formation of the folded zones, that is to say, the mountain chains, we are not at all certain. This absolutely necessary displacement is to the extent of many hundreds of kilometers or perhaps a thousand for a given chain; for all the chains of central Asia extending over hundreds of millions of years, it might on the whole amount to 3,000, perhaps 4,000, kilometers. Beyond that one knows nothing.

It is undoubtedly fascinating to group all the continents of the Carboniferous epoch, in order to separate them afterwards; it is undoubtedly enticing to consider the chains of islands as a train of stragglers behind the advancing continents, but it is not necessary. These are simply convenient hypotheses. No one is claiming that to-morrow others more convenient still will not be found. On the other hand, there is great objection to extensive mobility. The great objection is permanence; long permanence on the surface of the earth, of the two features of which I have spoken, the Circumpacific zone and the transverse zone, parallel to the Equator, and cutting in two the hemisphere opposite the Pacific domain.

Of the present drifting, supposing it exists, we will soon be advised by the near resumption of the measures of longitude with a precision heretofore unknown. You know that radiotelegraph already permits, or soon will permit, the giving at a certain moment the hour from a starting point, such as Paris, to all the great observatories of the world. One will deduce from it, within a small number of meters, the longitude of any point whatever from one of these observations in a comparison with the zero meridian. After some years, perhaps, one will thus know whether America is getting farther away from us, as Wegener thinks; whether it is fixed in relation to us; or whether the distance between us is diminishing, as I would be tempted personally to think, for reasons which it would be too long to here explain and which pertain to the rôle of the geosyncline that I ascribe to the Atlantic. But it is to be feared that the relative movement, if it exists, may be an extremely slow one, and that a century may be necessary to surely establish its existence. We shall then be condemned to die without knowing whether the At-

lantic is advancing or receding, and on that account many of us will find difficulty in consoling ourselves.

Twice before I have had the very great honor of speaking here. The first time in 1912, when I spoke of Atlantis. I discussed the disappearance of Atlantis, its sinking into the abyss, at a very recent period, so recent, as Plato tells us, that perhaps man was present at the cataclysm and suffered from it. The second time was in 1920; I spoke then of the history of the oceans through the ages, the successive formation of the Indian Ocean and the Atlantic by shrinkage and, by contrast, the long persistence of the Pacific domain to the state of special domain, perpetually agitated.

The theory of Wegener has not greatly changed my ideas on oceanic history, and I indeed believe I should speak to-day of Atlantis, of the Indian Ocean, and of the Pacific as I spoke of them in 1912 and 1920. The theory of Wegener is to me a beautiful dream, the dream of a great poet. One tries to embrace it, and finds that he has in his arms but a little vapor or smoke; it is at the same time both alluring and intangible.

But in all reality we can not conclude, we can not say, that there is really nothing in Wegener's theory; neither can we affirm that it does not contain some truth. Our knowledge is very limited. It is always necessary to close a lecture on geology in humility. On the ship earth which bears us into immensity toward an end which God alone knows, we are steerage passengers. We are emigrants who know only their own misfortune. The least ignorant among us, the most daring, the most restless, ask ourselves questions; we demand when the voyage of humanity began, how long it will last, how the ship goes, why do its decks and hull vibrate, why do sounds sometimes come up from the hold and go out by the hatchway; we ask what secrets do the depths of the strange vessel conceal and we suffer from never knowing the secrets. Most of us content ourselves with living, awaiting each day the morrow, which we hope will be better.

You and I are of the group of restless and daring ones who would like to know and who are never satisfied with any response. We hold ourselves together on the prow of the ship, attentive to all the indications which come from the mysterious interior, or the monotonous sea, or the still more monotonous sky. We console each other by speaking of the shore toward which we devoutly believe we sail, where we shall indeed arrive, where we shall go ashore to-morrow, perhaps. This shore not one of us has ever seen, but all would recognize it without hesitation were it to appear on the horizon. For it is the shore of the country of our dreams, where the air is so pure there is no death, the country of all our desires, and its name is "Truth."

THE PROBABLE SOLUTION OF THE CLIMATE PROBLEM IN GEOLOGY[1]

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I

In the following pages I have endeavored to give an interpretation, not only of the appearance of ice ages, but also of the greater changes of climate registered in the geological record. In view of the importance ascribed in this discussion to hypsometric conditions and land forms, I have named the theory the relief hypothesis.[2]

Kindred explanations have been put forward before. Lyell would find the causes of the great alternations of climate during past ages in the continuous changes of the distribution of land and sea which had been going on all through the geologic ages. J. G. Charpentier, in the first half of the nineteenth century, supposed that the glaciation of the Alps and other tracts had been greater formerly because these were much more elevated. Since then various hypotheses of continental elevation have been set forth as solution of the climate problem in geology. It is easy to discover the weak points in these suggestions and to understand why they have not been found applicable. But there is one strong point in all of them. They have looked for the causes of the geologic changes of climate in geographic changes which the earth may have undergone. The relief hypothesis follows the same lines.

This theory does not explain why ancient glacial formations, such as the Permian, are now found far from the poles, often near the Equator. In order to understand this and other very anomalous situations of climatic zones of the past, one can hardly avoid postulating migrations of the poles or the continents.

The question to be answered here is:

Why have some geological periods been characterized by glaciation and various other signs of cooler climate, while the earth in other periods was favored with very warm climates which extended their influence apparently to all parts of the globe?

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[1] Reprinted by permission from The Geological Magazine, April, 1924.

[2] Wilhelm Ramsay, "Die Reliefhypothese zur Erklärung der Klimaschwankungen;" Petermanns Mitteilungen, 1911, p. 335.

The very question arises from our knowledge that geological evolution has not been uniform. On the contrary, as is commonly understood and admitted, orogeny, volcanism, degradation, and aggradation, and all other constructive and destructive processes show great differences in their intensity from period to period, and these variations are cyclic and rhythmic. The measure of the rhythm is indicated by the formation of the mountain chains.

Since the beginning of the Cambrian period, the evolution of the earth has passed through three geologic cycles of higher order and commenced a fourth. The transition from one to another is marked by the unconformities which in the stratigraphical series follow the Caledonian, Hercynian, and Alpine diastrophism. The great cycles are:

Cycle—	Part 1	Part 2	Main orogeny
I	Eocambrian-Cambrian-Ordovician	Gothlandian	*Caledonian.*
II	Devonian-Lower Carboniferous	Upper Carboniferous	*Hercynian.*
III	Permian-Triassic-Jurassic	Cretaceous-Tertiary	*Alpine.*
IV	Quaternary		

The first part of each cycle comprises an anorogenic phase of long duration. The cycles enter then in a first orogenic phase, a forerunner of the main mountain-making movements. After this, relatively anorogenic periods follow in the second part of each cycle. From this point, however, disturbances become more frequent, and at the end of the cycle, the main mountain folding takes place, to continue here and there, with decreasing strength, in the beginning of the following cycle.

The above tabulation in cycles of the geological periods is in no manner meant to assert that these were of equal duration, nor that the corresponding phases from different cycles represent quite similar stages in geological evolution. It is of course possible to dispose the periods in cycles in many other ways. But however we arrange them, we shall find that the rhythm of orogeny has regulated the general course of the history of the earth.

Thus volcanic activity has always been not only geographically combined with the zones of folding and faulting, but also chronologically connected with the formation of mountain chains, being strongest during, and immediately after, orogenic times, feeblest in anorogenic periods.

The great transgressions and regressions of the sea follow the same rhythm. In the periods of orogeny and immediately after, there is considerable general regression. The land areas were extensive then, as they are at present. The greatest transgressions, again, appeared in the anorogenic intervals.

The relief of the continents has also changed in accord with the orogenic rhythm, a fact of special interest for the theory put forward in this paper.

The mountain folding, and all events in connection with it, brought the various parts of the earth's crust into positions which no longer corresponded to the previously existing isostasy. In consequence of this, there was again a tendency to new isostasy, resulting in elevations here and depressions there. These displacements were greatest after the diastrophism at the end of each cycle, while features hitherto prevailing in the aspect of the continental blocks were replaced by new ones.

The great disturbances enormously changed the relief of the foregoing period. Thus, at the beginning of a new cycle, not only were the land areas greater than at other times, they were also more elevated, and it was then that the loftiest mountains rose on the continents. Then, too, the sea had its greatest depth. For only so could it, in spite of its reduced area, contain the same masses of water.

The Quaternary period and the Recent time belong to such an era of high continents and deep oceans. The mountains, only formed in the later part of the Tertiary period, are still lofty, and in all continents there are old peneplains in which a young erosion has carved new valleys. This phenomenon is so common that all examples of typical peneplains referred to in literature are pre-Quaternary ones. This signifies, first, that before the crustal movements by which the different portions of the continents came in their present level, the land masses had been in a state of relative repose for so long a time that they were completely degraded, and secondly, that the altitude of most parts of the continents is at present greater than in the pre-Quaternary time. Indeed, we find undisturbed Tertiary marine deposits at high levels, and the most elevated of them belong to the oldest Tertiary beds, while younger occur at lower levels. Even Pliocene deposits lie at many places high above the beaches of both recent and Quaternary seas.

It is not astonishing that the elevation of the continents, with their highlands and mountains, reached its greatest altitude in Quaternary time. We may call to mind that tangential movements were still going on during this period in many mountains, and many remarkable faultings are equally young. Further, the now existing valleys were formed in Pliocene and at the beginning of Pleistocene time, as is well known and often emphasized. It is very probable, as Nansen[3] suggests, that in consequence of this erosion the mountain-ridges may have been raised by isostatical

[3] Fridtjof Nansen, "The Strandflat and Isostasy"; Videnskabsselskabets Skrifter: I. Mat. naturv. Klasse, 1921; No. 11, Kristiania, p. 305.

upheaval to levels higher above the sea than those at which the summits of the mountains stood before the erosion began.

There is thus good evidence that the relief of the continents gradually grew higher and more uneven in the course of the Pliocene and Pleistocene ages, and that the elevation of the mountains over the valleys, of the highlands over the lowlands, and of the continents over the sea, reached its maximum in the beginning of the Quaternary period, whereafter it has rather diminished. By analogy, we have the right to assume that the continents also had their highest and most mountainous reliefs at the beginning of the elder, i. e. of the Caledonion, Hercynian, and Alpinian cycles. Likewise, the relief must, in higher or lower degree, have been elevated and mountainous at the orogenic phases within the cycles, though not so high as after the three chief ages of diastrophism.

During the long anorogenic phases of the cycles, the mountains and hills were broken down and the continents finally peneplained.

The changes of relief show themselves also in the nature of the sediments. Conglomerates, sandstones, grits, and other coarse clastic rocks prevail in the systems deposited during and after the orogenic phases. They testify to the activity of running water with strong power of erosion and transport; that is, that the ground was high and sloped considerably. In the systems from the end of the anorogenic phases, again, muddy deposits and limestones are predominant. The rivers did not bring coarse material down to the sea, in many cases not even finest mud, since the land was low and plain.

The above suggestions concerning relief in the past and present may be briefly summed up.

Geological events have not proceeded uniformly, but cyclically. There were not at all ages lofty mountains and highlands in some regions, with plain lowlands, or even lower mountain districts, in others, as it is the case nowadays. For the formation and destruction of mountains has not during all time outbalanced each other. In some periods the former, in others the latter, process was prevailing. Only after the orogenic phases was the relief comparable to that of the present day, or still higher and more broken. For such a condition I will use the term *orocratic*. During anorogenic periods, again, the continents became more or less peneplained. I call such a condition *pediocratic*. Of course, there are gradual transitions between these two kinds of relief.

The changes of climate can also be fitted into the frame of the geological cycles.

In some ages in the history of the earth ice caps have covered vast areas, just as in recent times. I have named such periods

miothermic or less warm.[4] This term may also be used to designate the less-warm climate and the corresponding deposits. In most geological systems, however, we do not find any traces of glacial formations, or other phenomena evidencing a cold climate. There is rather every indication of favorable conditions for animals and plants over all the earth. For the corresponding periods and conditions, I have proposed the name *pliothermic* or more warm. We are now living in a miothermic period. It includes not only the Quaternary ice age, but also the interglacial and postglacial ages. For during them all, ice caps and glaciers existed. An ice age signifies aggravated miothermic conditions.

Which periods were miothermic, which pliothermic?

Traces of glaciation in the shape of tillite are found in pre-Cambrian formations. We know them, further, from the base of the Paleozoic series, and in the Eodevonian, Permian, perhaps in the oldest Cretaceous, and finally the Quaternary. They are formed in periods immediately after the great orogenic events, when the relief was orocratic. All other periods are pliothermic, and the obvious warmest coincide with the phases of least disturbance of the earth's crust and the greatest general transgressions, when the continents had the most pediocratic relief. Between orogeny and climate, there is an evident connection which I pointed out some years ago (1910). ("Orogenesis und Klima" cited above.)

Dacqué, who has elaborated this theme in still greater detail, has in his instructive treatise on paleogeography[5] illustrated graphically the changes of climate from the Cambrian time to the present day and the intensity of the orogenesy during the same space of time. Those interested will see in the diagrams in the work cited (pp. 432 and 449) a striking parallelism between these two curves.

How may the apparent relation between the formation of mountains and the deterioration of climate be interpreted?

It is hardly possible to explain it by astronomical theories concerning the ice ages, unless one supposes that the plication of mountain chains depends upon those astronomic constellations which have been thought to cause decline of heat on the earth's surface.

The hypotheses which find the cause of the ice ages in a protracted decrease of radiation from the sun, help us no more, for it is not probable that orogeny on the earth is produced by such a change in the sun.

It thus remains to look for the answer to the above question in circumstances connected with orogeny which have the effect that the

[4] Wilhelm Ramsay, "Orogenesis und Klima"; Öfversigt of Finska Vetenskaps-Societetens Förhandlingar, Helsingfors, lii, 1910, Afd. A, No. 11.

[5] Edgar Dacqué, Grundlagen und Methoden der Paläogeographie, Jena, 1916.

earth is less heated by the radiation from the sun than if mountain-making had not happened.

The carbonic acid hypothesis (Arrhenius) will here come under consideration. But an examination will show that no such diminution in the supply of carbonic acid as the theory requires to explain the severer climate—i. e., lessening of volcanic activity—happened in the miothermic ages. On the contrary, volcanism was most powerful during the orogenic phases and immediately after them, while again, it was least active during the anorogenic and pliothermic periods. Thus, even for these reasons alone the carbonic acid theory is not applicable.

The simplest and most probable interpretation of the connection between orogeny and climate lies herein, that the orocratic relief which the continents had after an orogenic phase, influenced the climate in such a manner as to establish miothermic conditions. When, again, the continents were pediocratic, as in anorogenic times, the climate became pliothermic.

It is well known that a climate is modified by the relief and the elevation of a region, and that with increasing altitude it gradually becomes cooler and even glacial. Further, mountains and highlands exercise a great effect as condensers of precipitation, as boundaries of climate, etc. But meteorologists and geologists reflect less often that the relief of the continents influences not only the local or regional climate, but the whole economy of the calories which the sun supplies. In the paper cited, "Orogenesis und Klima," I have endeavored to show that the influence of relief on the climate can be remarked in the following circumstances.

1. The more the radiation from the earth can be retarded, the more the temperature rises. In this storing of heat the atmosphere plays the chief part by its selective absorption, the effect of which has been compared with that of the glass on the hotbed. It yields the most favorable result on extensive lowlands, and if all continents were pediocratic, as supposed for pliothermic periods, they would profit by the sun's heat at the highest temperature. But this so-to-say ideal thermical state is disturbed by an orocratic relief. The air mantle upon the mountains and highlands is thinner and less dense than the atmosphere over the lowlands. In consequence, insolation certainly is greater, but the loss of heat by radiation into space has increased in a much higher degree. Moreover, as in all mountain regions the rising of warm and sinking of cold air are enhanced by the greater insolation and radiation, the loss will thus be accelerated. In the above comparison with the glass on the hotbed, the lofty parts of the continents can be regarded as holes in the glass. They not only chill the place just beneath them, but more or less the whole hotbed.

2. The orocratic relief augments the loss of heat still further by its influence on the circulation of air along the surface of the earth. The air currents, passing over mountains, high coasts, and other elevations in their way, are compelled to rise, and at the higher position their loss of heat by radiation is greater than if they had flowed at a lower level. When descending on the other side of the heights they hold less heat than when they rose, even if one takes into consideration the dynamic heating of falling winds.

3. On their way up-hill, the air currents get their temperature lowered and a great part of their vapor condensed. In consequence, rain and snow fall more frequently and abundantly when the relief is orocratic than they must do in periods when the relief is pediocratic. With the increased precipitation the temperature also is lowered. For the calories which the condensation sets free are but a compensation for the dynamic cooling of the air, and for the loss by radiation into space, and the fallen rain and snow, having normally a lower temperature than the air near the ground, demand great quantities of calories for their heating and evaporation.

If, again, the relief is pediocratic, the circulation of the winds would be more regular, and the precipitation diminished, at least at higher latitudes, and accordingly the loss of heat less. Besides, the air holds more vapor and has a greater capacity to retard the radiation into space.

4. The principal importance of the orocratic relief in producing a miothermic state is, however, that the lofty parts of the land reach up into colder layers of the atmosphere, where they will be covered with perennial snow and ice. The more numerous, the higher and vaster the elevated tracts are, the more extensive the glaciated areas of the continents. And all the circumstances enumerated above which follow with orocratic relief, cooperate to lower the snow line and thus to widen these areas.

The ice caps, when once formed, and the annual snow fields of longer or shorter duration, have furthered the evolution of the miothermic climate. Insolation, reflection, and radiation take place on snow fields in such a way that the heat from the sun is only used to a slight degree for raising the temperature. Great masses of snow remain unmelted. The melting of the rest consumes a large part of the heat of the warm season, not only the direct isolation, but in addition a considerable supply from the environs. Thus, the snow fields and ice caps cause a lowering of the temperature outside their boundaries, and the cold water from them runs far beyond the ends of the glaciers and deprives the neighborhood of heat.

5. More than other glacial regions, lands at high latitudes are responsible for the establishment of pronounced miothermic conditions. If there only exist high enough islands and continents,

ice caps will appear, extend their glaciers down to the sea, and send out their armadas of icebergs. To melt them enormous quantities of the heat reserve of the sea will be consumed. Cold water forms extensive superficial layers, and gradually fills the depth of the ocean right to the Equator.

6. The greater the ice caps grow, the more ice is bound in them which otherwise would run as water back to the sea. Consequently, its surface falls. Tylor[6] drew attention to this as early as the year 1868, and since then it has been discussed by many scientists. Nansen[7] has lately treated the question in detail. According to him, the surface of the sea would rise 1 meter, if the now existing glaciated areas were melted to an average depth of 24 m., and at the maximum of the Quaternary glaciation (altogether 50 million km,^{2} average thickness 1,000 m.), the land ice contained so much water that the sea may have been at least 130 m. shallower than it is to-day. Nansen has made in his calculations very moderate assumptions of the extension and thickness of the ice caps. Double the supposed thickness and more does not seem to be improbable. As we see, there must have been considerable changes of the sea level by this cause, and it is obvious, that with such a sinking of the sea, the snow line and the glaciers also must have moved downward.

Thus, miothermic conditions and ice ages are established as a consequence of orocratic relief.

If we now imagine the relief pediocratic, we shall find not only that the conditions producing glaciation and miothermic climate no longer exist, but also that the climate must have been pliothermic, much warmer than at present.

Even in the Arctic regions, the snow line lies at considerable heights above the sea level. This was the original condition also on the Antarctic continent, where the now existing snow line at the sea level has resulted from the active cooling effect of the huge glaciated land and the passivity of the cooled sea. This proves that, when the continents are peneplained, as assumed, they in no place reach up to so high a level that perennial snow could be formed and ice caps cover them. The disadvantageous effect which glaciation has on the climate, fails. Heat is not taken from the atmosphere to melt ice, nor from the hydrosphere, for there are no longer any icebergs in the sea. Cold water does not extend over the surface of the sea at high latitudes, and the cold water in the depths receives no addition, but the oceans are gradually heated to ever greater depth, and the surface layer of warm water grows thicker and warmer. The sea currents and winds bring more heat from the low latitudes to

[6] Alfred Tylor, "Evidence and Cause of Great Changes of the Sea Level During the Glacial Period": Geol. Mag., Vol. V, 1868, p. 576.

[7] Loc. cit., pp. 229–238.

the polar regions, where the heated sea remains unfrozen and the climate becomes genial. If we further consider the regular circulation of the winds, disturbed by no mountains or elevations, and the augmented selective absorption of the atmosphere, we shall understand the conditions which led to the pliothermic climates, of which the fossils and sediments give evidence.

We need not look for any other cause of the great changes of climate during past periods or of the ice ages, than the changes of relief which the continents have undergone.

II

It is also generally admitted that a mountainous relief is an essential condition of glaciation. But against the assumption that orocratic relief is the cause of ice ages, it has been argued that the relief has not shifted during the Quaternary period in a manner corresponding to the great differences in the climate of the ice age and recent times and of the repeated glacial ages and interglacial ages. And consequently, as change of relief can not be the cause of the Quaternary alternations of climate, the actual cause of them, when once found, may also prove to include a better explanation of the greater climatic changes than the relief hypothesis. This objection does not destroy the theory.

For, if a miothermic climate is established—owing to an orocratic relief, as I think, or to other causes—it will for a long time oscillate between severer and milder conditions before a certain equilibrium is reached. Paschinger [8] has recently tried to show that the influence exercised by glaciation itself upon the level of "the zone of maximal precipitation" and on its own growth and decay, brings with it cyclic variations great enough to lead to glacial and interglacial stages. Certainly those meteorologic factors help to enhance and diminish glaciation, but it seems that the repeated accumulation and dissolution of the ice caps is due to alternating elevations and depressions of the glaciated regions.

This was suggested by Upham,[9] referring to Jamieson's [10] assumptions that the regions had sunk under the load of the ice caps and been raised by the removal of this load. Meanwhile, he combined with his theory features from the astronomic explanations of the

[8] V. Paschinger, "Die Eiszeit ein meteorologischer Zyklus": Zeitschrift für Gletscherkunde, xiii, Leipzig, 1923, pp. 29–65.

[9] Warren Upham, "Probable Causes of Glaciation." In G. F. Wright, "The Ice Age in North America," London, 1890, Appendix, pp. 573–595. "Pleistocene Climatic Changes": Geol. Mag., 1894, pp. 340–349.

[10] T. F. Jamieson, "On the History of Last Geological Changes in Scotland": Quart. Journ. Geol. Soc., xxi, London, 1865. "On the Causes of Depression and Reelevation of Land during the Glacial Period": Geol. Mag., 1882, pp. 400–407 and 457–466. "On Some Changes of Level during the Glacial Period and Their Causes": Geol. Mag., 1887, pp. 344–349.

ice ages, and, further, thought that subsidence of one region caused uplift of other portions of the earth's crust; so that glacial conditions may have prevailed alternately in the Northern and Southern Hemispheres or in North America and Europe. But there are weighty reasons enough for assuming a simultaneous appearance, not only of the glaciations on the Northern and Southern Hemispheres, but also of the successive Quaternary ice ages in different quarters of the world.

The supposition that the dissolution of the ice caps resulted from the depression of the regions under the load of the ice, has, however, been considered fallacious.[11] The depression being, namely, at isostatic equilibrium only about one-third of the thickness of the ice, the surface of an ice-covered region is always more elevated than the region was before its glaciation. Consequently, the ice cap does not disappear. Such a reasoning is right, if one has in view only the isostatic depression. But here come the changes of sea level, too, as we shall see.

At the beginning of the Quaternary period the continents had orocratic relief, as at the beginning of the earlier miothermic ages. Their higher parts became glaciated, the ice caps grew bigger, as described above, the sea was chilled, and the climate deteriorated. Enormous quantities of water being confined in the land ice, the sea level, and with it the snowline, sank. The ice fields grew still larger, until they extended to so low levels or latitudes that the heat of the summer stopped them at a certain maximum. However, an equilibrium between glaciation and melting did not yet come about. For as the ice caps got bigger and thicker, they loaded more and more the areas occupied by them. The crust of the earth gave way and began to sink, but not in the same proportion as the ice load increased. The depression certainly reached its greatest depth only after, and long after, the maximum of glaciation, just as in the contrary case, the upheaval of Fenno-Scandia and other formerly glaciated regions has continued long after their release from the weight of the ice, and still continues.

As the depression proceeded, the ice-covered regions came gradually into lower positions in relation to the levels of the snow and glacier lines for maximum glaciation. The ablation now gained upon the advance of the glaciers; the ice masses began to diminish. The addition of water to the sea raised its level, and thus also the snow line. This accelerated the melting of the ice, the sea level rose steadily, and so on. The more the sea level rose, the better the warm sea currents could pass over submarine thresholds and penetrate to higher latitudes. All this worked together to lessen glaciation and hastened the amelioration of the climate.

[11] R. D. Salisbury, Editorial note: Journal of Geology, II, Chicago, 1894, pp. 222–224.

Meanwhile, as the weight of the ice caps diminished to correspond to the depression of the ice-loaded area (i. e., as the average thickness of the ice was about three times the amount of the depression), the crustal sinking had reached its maximum and reversed in upheaval. But the dissolution of the ice, once begun, continued because the steady addition of water to the sea raised the snow line. In the race between the upheaval and the rising of the sea level, the latter won. When delivered from ice, the just glaciated regions were still deeply submerged.[11a] Further, the snow line may have risen more than the sea level in consequence of the amelioration of the climate by the decrease of the glaciation. The melting, the rising of the snow line, and the general improvement of the climate proceeded rather in an accelerated degree, on analogy with the case in late-glacial time in Fenno-Scandia investigated by De Geer [12] and Sauramo.[13] Finally an interglacial stage with restricted glaciation and genial climate appeared.

But the loftier portions of the regions were gradually raised anew above the snow line and glaciated. All the consequences of this pointed out in the foregoing pages led to a new general ice age, again followed by an interglacial stage, and so on.

Above, the isostatic rise of the sea floor by the abstraction of water from the ocean and the subsidence of ice-covered land is omitted, as also the reverse events. If considered, they should accent the supposed effect of crustal movements on growth and decline of the ice caps.

The cause of these oscillations (fig. 1) between severer and milder miothermic climate is, then, that the land movements due to the increasing and decreasing of the ice caps have their maxima and minima at other points of time than the variations of the ice caps and of the sea level (snow line). In the course of time the amplitudes of the successive oscillations must decrease until a balance in the miothermic climate is attained: moderate glaciation with isostatic equilibrium between depression and ice load, cessation of upheaval or submergence of the formerly glaciated lands. We are not yet at that point. I think, with Nansen,[14] that the last postglacial transgression of the sea in Fenno-Scandia indicates the maximum of dissolution of the ice caps and the highest position of

[11a] Wilhelm Ramsay: "On Relations Between Crustal Movements and Variations of Sea-level During the Late Quaternary Time," Bulletin de la Commission Géologique de Finlande, No. 66, Helsingfors, 1924.

[12] Gerard De Geer, "A Geochronology of the Last 12,000 Years": Compte rendu du XI Congrès Géologique International, Stockholm, 1910. pp. 241–253. "A Thermographical Record of the Late Quaternary Climate": Die Veränderungen des Klimas seit dem Maximum der letzten Eiszeit (Congrès Géol. Intern., 1910), Stockholm, 1910, pp. 303–310.

[13] Matti Sauramo, "Studies on the Quaternary Varve Sediments in Southern Finland": Bulletin de la Commission Géologique de Finlande, No. 60, Helsingfors, 1923.

[14] Loc. cit., pp. 286–287.

the sea level. The climate then was most favorable and has since declined.

In the diagrammatic presentation of the alternation of glacial and interglacial stages, it is not to be supposed that this proceeds in just the same way in different regions. Their varying size and altitude make it possible that their maxima and minima of glaciation or upheaval and sinking will not absolutely coincide, and the glaciation of different regions not be of equal duration. Further, their geographical situation can in many ways alter the influence of cold or hot sea currents, winds, and other agencies. Notwithstanding, the changes of climate must on the whole correspond in the different regions all over the globe, regulated as they are by the general chilling and heating of the oceans and by the general sinking and rising of the sea level.

FIG. 1.—A schematic sketch illustrating the relations of glaciation, crustal movement, and oscillation of sea level

The theory here proposed contains a general thesis: That the alternating pliothermic and miothermic conditions depend upon changes between pediocratic and orocratic relief, and a special thesis that the succession of glacial and interglacial ages during a miothermic period depends upon isostatic and eustatic oscillations of level. The theory thus sees the causes of the different climates during past eras in different geographical circumstances. Attempts to solve the puzzling question from this point of view were made almost a hundred years ago and have never been abandoned. One by one the facts and ideas on which the above theory is founded have been put forward and with the increase of our geological knowledge they have grown ever clearer and more convincing. I believe, therefore, that the relief theory will be approved as the true solution of the climatologic problem in geology, though it may be only after discussion and improvement.

A MODERN MENAGERIE; MORE ABOUT THE NATIONAL ZOOLOGICAL PARK

By N. Hollister

[With 18 plates]

The zoological garden idea is a very old one, and its inception dates back beyond all written history. It is certain that primitive man early began to surround himself with captive beasts, some of which became the progenitors of our modern domestic animals. Collections of wild animals formed a conspicuous part in civil and religious life throughout many of the early civilizations, and the menagerie, both public and private, developed into an institution of most remarkable proportions and importance. The ancient Egyptians kept great collections of living animals, including not only the native species but others brought from distant parts of the then known world. In the United States National Museum is a large case of thousands of bones, dating from about 2000 B. C., which were collected by Doctor Hrdlička from tombs in Egypt. This great lot of bones contains the remains of many species of wild animals, and the number of big bears is remarkable. The ancient rulers of Mongolia and of China maintained deer parks and menageries; and the great interest of the Greeks and the Romans in collections of living animals is well known.

In the New World, numbers of native animals were early domesticated, and the Aztec kings kept well arranged collections of wild beasts and birds for the instruction of their peoples. The first American buffalo seen by European eyes was confined in the menagerie of the last Aztec emperor of Mexico, Montezuma; this was nine or ten years before the buffalo was discovered in a wild state to the northward, and the captive animal had been brought not less than four or five hundred miles to the Aztec zoo.

There is always something fascinating about the capture, taming, and care of wild animal pets; and almost any one who has, as a child, experienced these joys, appreciates, later in life, the modern zoological garden. That the zoological garden is one of the most popular of municipal enterprises is evidenced by the great activity in its de-

velopment in recent years throughout the civilized world. In America, particularly, the number of zoos has increased enormously of late, and requests for information on development, cost, and care are coming in to the Smithsonian Institution from cities, large and small, at a constantly increasing rate.

The attendance at the National Zoological Park now regularly exceeds two million visitors annually, and in 1924 reached the record figure of 2,442,880. The park was established by an act of Congress approved April 30, 1890, "for the advancement of science and the instruction and recreation of the people," and has been, from the first, under the direction of the Smithsonian Institution. When the present site was occupied in 1891, a small collection of animals then kept near the Smithsonian Building and known as the Division of Living Animals, United States National Museum, was moved to the new location. The National Zoological Park, like the National Gallery of Art, is thus a direct offshoot of the National Museum. At that time the only important zoological gardens in America were in Philadelphia and Cincinnati; although some few other cities maintained small city-park menageries like the one still in Central Park, New York.

The National Zoological Park was, at the time of its establishment, some distance from the main part of the city of Washington, but the rapid growth of the city to the northwest has entirely surrounded it, and now it is in the center of one of the best residential districts. Fortunately, its area of 175 acres, much of which is wooded land, gives sufficient space and seclusion, and the city development has added to, rather than detracted from, the value of the site for zoological garden purposes. Rock Creek Park, later established, joins the National Zoological Park on the north.

Visitors to the Zoological Park daily remark on the splendid collection of animals, the cleanly quarters, and the care and effort that must be taken to provide such an interesting and varied collection of the mammals, birds, and reptiles of the world. Few realize, however, the magnitude of the task involved, the varied requirements of bird and beast, or the expert services necessary for their health, comfort and care.

The modern zoological garden is a very different affair from the old-time menagerie. New plans for the comfort and health of the animals, new methods for more satisfactory exhibition, new arrangements for the constantly increasing numbers of visitors, are all the time being considered, and each improvement is eagerly adopted as soon as its merits are proved and funds are available for its realization.

Animals are expensive, and many of the rarer species are not easily obtained at any price. The opportunities to secure any but

the most common and constantly imported species are of irregular occurrence, and few may be had at the moment no matter how much money may be available for their purchase. The first consideration, then, is the health of the animal; contentment and health being necessary to long survival, and if the unusual species are to be shown regularly and for long periods the most expert care is often necessary to maintain in proper condition the specimens that may be secured.

Few persons realize how much ingenuity and resourcefulness are regularly expended to make wild animals the healthy and contented pets they usually become in captivity. The individual animal, as well as the species, must be studied. Some do best in large inclosures; some best in smaller cages. It is frequently found that certain parrots and other birds, perhaps reared from nestlings by some native woman, are extremely unhappy in large cages, refuse food, and would soon die unless promptly returned to a small cage. Then they are obviously very happy again and most often live for many years in perfect health and contentment. An exceptionally fine puma in the National Zoological Park, most contented and thrifty in a small old-fashioned cage—one of the first cages ever built in the park and scarcely larger than a circus wagon cage—simply "went to pieces" and refused to eat anything whatever when transferred to a fine, large, airy, outdoor inclosure. He was promptly returned to his dingy old cage, greatly to his delight and benefit; in a short time he was fat and sleek again.

It was once advocated by a famous animal lover that wild animals in captivity should be changed frequently to strange cages, where they could enjoy new surroundings and a different view. All experienced animal keepers know the fallacy of this argument. Animals grow to feel safe and contented in familiar, even though restricted, quarters; but are frequently greatly distressed and upset in strange surroundings or when any unusual activities are going on about them. If animals were frequently changed the loss would be great. Contented animals in small quarters very often live far beyond the age usual to wild animals of the same kind. Few persons realize the home-loving character of wild animals, and how limited the normal ranges of individuals are, unless the creatures are driven from place to place by predatory beasts and man. Every wild animal is continually searching for a "safety zone," and this is exactly what quarters in a well-conducted zoological park supply.

THE NATIONAL COLLECTIONS

There are now nearly 1,700 animals in the collection of the National Zoological Park, including mammals, birds, and reptiles. The

collection of mammals is one of the finest in the world, and is particularly notable for the large number of rare species seldom seen in collections of living animals. There are now 13 different species of bears on exhibition, represented by 23 individuals, including a fine specimen of the glacier bear (*Ursus emmonsii*), the first of its kind ever to reach a zoological park. Other carnivores in this notable collection include 12 species of wild dogs, the most unusual of which is the South American bush dog (*Icticyon venaticus*); an aard-wolf (*Proteles cristatus*), a rare member of the hyena family from South Africa; and 14 species of the cat family, among them, in addition to the regular exhibition of lions, tigers, leopards, etc., examples of the cheetah, or hunting leopard (*Acinonyx jubatus*), snow leopard (*Felis uncia*), and clouded leopard (*Neofelis nebulosa*).

The collection of monkeys now contains about 30 species, among which may be mentioned such rarities as the gelada baboon (*Theropithecus obscurus*), 4 species of mangabeys, and the Moor macaque (*Cynopithecus maurus*). There are 55 species of hoofed animals, many of them represented by fine breeding herds. The reindeer, Alpine ibex, Rocky Mountain goat, Rocky Mountain sheep, musk ox, black rhinoceros, Baird's tapir, African and Sumatran elephants are among the unusual species shown.

Among the birds, the waterfowl, cranes, birds of prey, and ostriches and their allies are especially well represented, and the collection contains many rare varieties. The kiwi (*Apteryx mantelli*), Hawaiian goose (*Nesochen sandvicensis*), California condor (*Gymnogyps californianus*), and kagu (*Rhynochetos jubatus*) may be mentioned as of especial interest in this connection. There are now on exhibition 190 parrots of 50 different species.

The prize exhibits in the reptile department are extra fine specimens of the anaconda, some large pythons, one of them 25 feet long, and 4 specimens of the virtually extinct giant tortoise of the Galapagos Islands.

A unique exhibition is the North American Waterfowl Lake, wherein are shown only such species of ducks, geese, and swans as are known to occur in North America. This restriction to native species is very much appreciated by bird students and sportsmen, who are confused if exotic species are mixed with native forms. At present this inclosure contains about 200 waterfowl of 35 different species. The lake has been constructed and planted to represent one of the woodland ponds common to parts of the eastern United States, and its natural appearance makes it differ greatly from the highly artificial lakes usual to zoological gardens. Fresh water from Rock Creek is constantly flowing through it, and a dam in

the creek below the inlet to the lake assures an even level of fresh water.

The National Zoological Park has always been particularly successful in the breeding and rearing of animals. In addition to large numbers of deer, antelopes, bisons, camels, llamas, guanacos, yaks, and other ruminants, many lions, tigers, pumas, and other great cats, bears, wolves, kangaroos, etc., have been reared. Tapirs and hippopotamuses have been regularly reared also, and in recent years great success has been obtained in breeding such unusual species as Rocky Mountain sheep, mountain goats, and reindeer.

Young animals are always of intense interest to visitors, and it is a great satisfaction to the keepers to be able to show them. Nothing, perhaps, speaks so highly for the condition of a collection of living animals as regular success in rearing the young. Baby lions, tigers, bears, and monkeys always attract and hold the attention of great crowds of enthusiastic visitors.

One of the most remarkable instances of memory by a lower animal for a human friend that ever came within my personal observation had to do with a baby hippopotamus born in the park. The little fellow had been a great favorite with his keepers, who always called him "Buster"; and when, at nearly 2 years of age, he was exchanged to the St. Louis Zoological Society, Mr. W. H. Blackburne, the head keeper, accompanied him in a special express car on the journey. For a large part of the trip the car was attached next behind the locomotive tender, and the young hippo was naturally distressed and nervous. He was perfectly contented and quiet, though, if Mr. Blackburne sat at the head of the crate and allowed him to suck his fingers, and as a consequence Mr. Blackburne spent the better part of one whole night in this position with his hand in the mouth of the baby hippo.

On his arrival at the St. Louis Zoological Gardens the hippo was rechristened "Steve," became a general pet, and was known to everyone by his new name. Nearly two years later Mr. Blackburne and I were visiting the St. Louis zoo and came into the hippo house, with a number of other people, just at feeding time. The young hippo, now very much grown, was eager for his food, which was then being placed for him at one end of his large indoor inclosure. Mr. Blackburne hailed the animal with his old-time "Hello, Buster!" just as he had done hundreds of times in Washington two years and more before. The response from the hippo was instant; he turned at the sound of the old name, and after Mr. Blackburne went back of the guard rail and the hippo had smelled of his hands and received the old-time pats on his great lips, absolutely identifying his old friend, he refused, for the time, to pay any attention to

his food or his keeper. There was absolutely no mistaking his actions; he was at first startled, then puzzled, and then, as his memory awakened, highly pleased. His recognition was positive. It was a most interesting and instructive lesson in animal psychology, but had I not actually witnessed the performance I am sure I should have been somewhat skeptical of a tale of such intelligence and memory on the part of a hippopotamus. Many interesting tales of the affection of animals for their keepers could be told by those familiar with the zoo.

Zoological garden men are always interested in longevity records and take pride in the number of years that certain animals have been kept in their collections. The death rate at the National Zoological Park has always been kept very low, and the records show some splendid accomplishments in keeping wild animals in perfect health for periods long above the average for their kind.

At the present time there is living in the garden only a single animal that formed part of the original collection moved from the Smithsonian Institution when the park was first occupied in 1891. This is a sulphur-crested cockatoo (*Kakatoe galerita*) which was presented to the Institution on April 19, 1890, and has thus been in the collection for 35 years. The bird was fully adult when received, and the few employees who remember it as it first came say that it is unchanged in appearance or vitality. Only seven other old residents of the park date back to the nineties, as follows: An American white pelican received from Yellowstone National Park in 1897; a bald eagle received from Gen. Nelson A Miles in 1898; an Alaskan bald eagle received from Gen. R. A. Alger, Secretary of War, in 1898; two giant Galapagos Island tortoises received in 1898; a brown pelican, 1899; and an anaconda, a gift from the Governor of the State of Pará, Brazil, received in 1899.

Some other old-time residents still living in the park, with years of arrival, are: Yakutat bear and king vulture, 1900; polar bear and California condor, 1901; yak, black stork, and two roseate cockatoos, 1902; Kadiak bear, emu, European white pelican, two California condors, and sacred ibis, 1903; rhesus monkey, sloth bear, Somaliland ostrich, Australian crane, and European raven, 1904; Polar bear, crowned crane, and European white pelican, 1905; American bison, red deer, red-and-blue-and-yellow macaw, lesser vasa parrot, and Indian white crane, 1906. There are numerous records of other animals still living in the park of which the management is very proud.

Certain North American animals have always been difficult to keep in zoological gardens; just why is not always exactly clear, as some of their exotic relatives are frequently among the easiest of

species to maintain. The National Zoological Park has some good records for certain of these species, including one of a mule deer that lived in the collection for 13 years 10 months and 26 days; a Columbian black-tailed deer for 11 years 2 months and 22 days; a Newfoundland caribou for 9 years 10 months and 17 days; and a pronghorn antelope for 5 years 4 months and 15 days.

Some other interesting longevity records in the files include a harpy eagle (*Thrasaëtos harpyia*), 17 years 10 months 26 days; great black-backed gull (*Larus marinus*), 17 years 4 months 22 days; Steller's sea lion (*Eumetopias jubata*), 17 years 3 months; gray wolf (*Canis nubilus*), 16 years 3 months 5 days; northern wild cat (*Lynx uinta*), 15 years 3 months 27 days; and a wandering tree duck (*Dendrocygna arcuata*), 15 years 21 days. A female South American tapir lived in the park for 20 years and 10 days, during which time nine young were born from her, seven of which were successfully reared.

WHERE THE ANIMALS COME FROM

Many visitors take a collection of living animals for granted; they never seem to wonder where the specimens are obtained or how they reach the park. They are familiar with the zoological gardens in numerous cities, visit and enjoy them frequently, have their favorites among the various animals, and take it all as a matter-of-fact provision for the enjoyment and education of themselves and their children. In conversation with such persons they frequently admit that they have never wondered much about it, but suddenly become greatly interested. "How *do* you get all these animals?" they at once want to know.

While some living animals are received from all sorts of unexpected sources, by far the greater number of those on exhibition come through regular channels—the importing dealers. A native lad in India, Africa, or South America captures a young animal and keeps it as a pet, just as many American country boys do; eventually this animal and others find their way into the hands of traders in some seaport; they are bought by the agents of importers or by independent animal buyers and eventually land in New York or San Francisco in the establishments of the dealers. Large stores, warehouses, and "farms" are maintained by these dealers and some long-established firms are engaged in the animal business in various large seaport cities of the world. New York and San Francisco dealers import the bulk of the animals received in the American trade. Animals are purchased by agents of these firms in large or small lots from smaller dealers or natives in all parts of the world, shipments are assembled, and, accompanied by expert keepers, are carried to

the receiving port. From here they are scattered to retail dealers, zoological gardens, private fanciers, and shows throughout the country.

A large part of this trade consists of canary birds, parrots, and other popular cage birds and pets, but some very large shipments are made up almost entirely of larger mammals, reptiles, and rare and unusual birds. Some of the largest shipments received in the United States have been brought by traders who travel about, from country to country, buying and selling such wild animals as they can secure. The capital required for such trading is large and the risks are great. Only a few of the most expert and energetic of men are able to carry on such a roving business successfully without the added regular trade in staple species enjoyed by the regularly established dealers.

The National Zoological Park, through its parent organization, the Smithsonian Institution, receives numerous animals as gifts to the United States Government from foreign governments and scientific societies, and from American consuls stationed in out-of-the-way regions. The original act of Congress, in which the National Zoological Park was placed under the direction of the Smithsonian Institution, authorized and directed the heads of executive departments of the Government to "cause to be rendered all necessary and practicable aid" to the Regents of the Smithsonian Institution in the acquisition of collections for the Zoological Park. Especially fine collections of rare and valuable animals have been received through the efforts of American consuls and through transfer from bureaus of other executive departments. Numerous animals presented by other governments or by individuals to the President of the United States have been transferred to the park. Notable collections of this kind were the gifts of rare animals sent by the late Emperor Menelik of Abyssinia to President Roosevelt. A magnificent Somaliland ostrich, included among these gifts from Menelik in 1904, is, by the way, still living in the collection. The Canadian, New Zealand, and other Governments have sent shipments of desirable animals not otherwise obtainable. Patriotic American travelers in foreign lands frequently collect or purchase strange animals and bring or ship them to the National Zoological Park. Many animals are received in exchange from other gardens, often through the importers or dealers, who can readily handle the surplus stock reared in the park. Certain reliable animal firms in San Francisco and New York receive and care for shipments of animals for the National Zoological Park. The animals are in such cases usually given a period of rest and special treatment before being forwarded on to Washington.

Through the courtesy of the express companies, shipments of living animals for the National Zoological Park often are given special care in transit, and, if desirable, telegraphic instructions are sent agents along the route. Different animals require different treatment on arrival at the park. Some may be liberated at once in the inclosures while others are kept in special retired quarters for short or long periods of rest and general adjustment to the surroundings and climate. In any case the newly arrived individuals have almost continuous observation for a few days, and all sorts of emergencies are prepared for. In exceptional cases such animals may be kept in retirement for months before they are finally, in the very best of condition, placed on exhibition to the public.

Certain kinds of animals from certain countries are, from time to time, subject to quarantine or even embargo. This is owing to outbreaks of stock diseases in foreign countries, all of which are promptly reported to the proper American authorities. For months, or even years, at a time it may be impossible to import directly from some foreign district ruminant or other animals subject to a specific disease. Some heart-breaking experiences result from these very necessary regulations, and excessively rare animals, never before or since obtainable, have been lost on account of them. But zoological garden officials are just as anxious as the stock breeders to keep animal diseases out of the country and are, or should be, ready at all times to cooperate with the quarantine division. So far, happily, no outbreak of any stock disease in this country has been traced to a zoological garden.

PRACTICAL LESSONS IN KINDNESS TO ANIMALS

In the modern, up-to-date zoological garden may be seen the finest examples of "kindness to animals." The men engaged in the work are selected for their feelings toward animals. Kindness and devoted attention are essential in maintaining their charges in health. No cruel, brutal, or inhuman act would be tolerated in any well-conducted zoo, and employees who do not show a thoroughly deep-seated or natural love for animals and an absolute freedom from "temper" are promptly released or transferred to work other than in the animal division.

There are, of course, some few good citizens who object on general principles to animals being kept in captivity. As a rule these people are not familiar with the facts or with conditions in our modern zoological gardens. We have known the most pronounced antizoo-fanatics to become completely converted after a day in the National Zoological Park, under the private guidance of an animal-loving employee, and to become much interested and sympathetic

thereafter in the work of the zoo. It is hard to understand the reasoning of a fanatical "animal lover" that would rather see animals killed than captured and made pets for the instruction and amusement of thousands of other equally good animal lovers. The extremists, who wish to abolish zoos, do not tell us what is to be done with these pet animals, and apparently have never considered the saving, by methods of domestication, of species doomed otherwise to extinction.

A recent outbreak against the zoological gardens had to do with the exhibition of specimens of the American eagle. At a meeting of one of the societies concerned with such matters, according to newspaper reports, it was argued that it is "unpatriotic and inconsistent to imprison for life the noble bird that has been chosen to typify the proud, free, and lofty spirit of America." It was further urged "that the eagles in captivity at the National Zoological Park and other places be liberated." Now, the eagles in the National Zoological Park have been almost invariably rescued from death. The park does not encourage the capture of eagles and always advises against the destruction of the birds or their nests. These that we have on exhibition have been trapped or shot, and we have taken them and brought them back to health. Were they liberated, it is certain that they would be promptly shot. The hand of almost every man is against the eagle, the bird is without legal protection in most States, and in some places bounties are actually paid for its destruction. Almost everyone shoots or traps an eagle whenever possible, and the wonder is that the bird exists as a wild creature in America to-day. Egg hunters know virtually every nest in many parts of the United States and rob them from year to year. The eagles in the zoo are seen and admired by millions of visitors who would never see a live eagle, especially at short range, in all their lives in any other way. They are regularly used as models by artists, and hundreds of photographs and drawings have been made of them in the years past, both by ornithologists and engravers. The beautiful eagles on our Government bills and bonds have been made directly from these very birds. What is needed is not protection for the eagles in the zoological gardens, but for the eagles left in a wild state. If the societies so distressed over the eagles in captivity would only join forces with the officials of our most prominent zoological gardens, who are doing all in their power to obtain legal protection for the eagles, they would indeed be doing some practical good in the cause of the wild creatures.

When one considers how rapidly the wild animals are being exterminated from the face of the earth, and what cruel methods are employed in hunting and trapping for meat, furs, hides, and oil, and how man's use of the land is depriving whole species of all

their range, it is easy for the well-informed animal lover to feel satisfied that the life of a contented, breeding family of animals in a zoo paddock is preferable to a fearsome struggle against unbeatable odds and certain extermination in a wild state.

BEHIND THE SCENES IN THE ZOO

Almost everyone is familiar with what is to be seen in the zoological garden from without the guard rails. Something of the activities behind the scenes may be interesting. Take, for example, the cook house. Here the chef in charge gives out to each keeper the ration for the day: Hot boiled rice from the fireless cooker for the morning feed of the monkeys; specially baked bread for the bears, carefully taken from the rack of day-before-yesterday's baking; hard-boiled eggs, fruits, vegetables, milk, meats, and fish. With about 1,700 animals of nearly 500 different species to care for, the head keeper and the property clerk must supply the chef and other assistants a great variety of foodstuffs. While hay, grain, and meat naturally form the great bulk of this provision supply, most of the articles of food used in the average home are at some time, even if only in small quantity, used for the animals in the zoo.

A large garden, operated in connection with the park, supplies kale, spinach, lettuce, Swiss chard, and beet tops. The lawn clippings are all eaten by the ruminants and waterfowl, and trimmings from trees—the leaves, bark, and small twigs—are used by the browsing animals. An orchard has been set out and it is expected that soon all of the apples that can be used will be grown in the park.

Each man in charge of some special kinds of animals visits the food house and sees to the proper preparation of the day's food for his charges. The meat is cut, fish trimmed, vegetables, fruits, and stale bread chopped in electric choppers; bone is ground. Almost any kind of food may be requisitioned by the keepers in an emergency. One keeper in charge of the ostrichlike birds was having difficulties with a sick cassowary. All food was refused by the bird. The keeper, a man of great experience, asked for a few pounds of Malaga grapes. These were promptly supplied, the patient was pleased, and a rare specimen worth many hundreds of dollars was soon "back on his feed" again.

The market truck visits the wholesale market of the city early each morning, returning to the park about 10.30 a. m. The special requirements for the day, which may include almost any delicacy, even to Malaga grapes or oranges, are included with the regular day's supply of perishable staple foods.

Some of the animals must be fed several times a day; some, like the lions, tigers, and other big cats, only once a day six days in the

week, with one day out of seven of complete fasting. Some of the reptiles eat only once every month or two. Some young animals must be fed throughout the night; always, there are two experienced animal men on duty at all hours of the night to look out for these special charges or for new arrivals that the stork may bring. Curiously enough, a fine large European stork in the park once died the day after the birth of a baby hippopotamus.

One of the great problems in the zoo is to keep people from feeding the animals. Unfortunately, as much as people like to do this, the officers in charge must frown on the practice. Sickness and even death are not infrequently due to such acts of mistaken kindness on the part of visitors. Peanuts are not the best of food for all animals, especially in such quantities as would be furnished on a day of large attendance, were the keepers and guards lax in their duties. It is particularly distressing to see a person take a bite from a piece of cake or fruit, remove it from his mouth, and toss it to a rare and delicate monkey. If such miscellaneous feeding were allowed the death rate among those animals especially susceptible to the contagious diseases would unquestionably be greatly increased. Certain native plants are highly poisonous to some of the animals, so that it is not entirely safe to allow uninformed visitors to pass green food into the inclosures. I am sure that every zoological garden man in America would be glad if every visitor refrained from tossing anything *whatever* into a cage or paddock.

In addition to the animal division and the office force the Zoological Park must, of a necessity, employ gardeners, mechanics, police, laborers, and attendants. The grounds must be planted and kept in order, the Government's property and the visitors must be protected, and repairs must be made to buildings, cages, walks, and roads. The main exhibition buildings are economically heated from a central plant, and around this plant are grouped the machine shop, blacksmith shop, paint shop, and carpenter shop. Repairs involving the security of animals or the safety of visitors can not be delayed, and are sometimes immediately urgent.

The expert mechanics on the list of permanent employees are able to do almost any kind of construction work in wood and metal, and almost all of the mechanical work done in the park—from the construction of a building to the making of an automobile road—is done by the regular force with the assistance of such temporary laborers as may be required.

THE RECORDS

Every animal received at the National Zoological Park is catalogued, given a serial number, and further recorded on a large filing

card. The name, sex, age, history so far as known, and condition are all entered. The subsequent history of the animal is recorded on the back of its card so that the records of accidents, sickness, births, or any other important incident in its life are readily ascertained. On the removal of the animal by death, exchange, or for other reason the final chapter in its life in the zoo is entered on the card and the card is transferred from the file of living exhibits to the permanent file of past residents of the park. If the animal dies, the cause of death, with the autopsy report, is entered with the final record. The information thus readily available on any animal or group of animals kept in the park since its foundation is often of great importance, and the value of the complete records increases from year to year.

In every community of 1,600 or 1,700 people, some one is pretty likely to be ill. It is so in the zoo. Every day each animal is carefully observed and any signs of illness are promptly reported to the head keeper. Most of the ailments are slight, and prompt recovery follows proper attention. If necessary, the animal is removed to the hospital building for isolation and better facilities for treatment. Always there are deaths, but the rate is very low, and, as mentioned before, many species are kept long beyond the usual period of life for a wild animal. Old age is protected and prolonged in the zoo; in the wild state all animals past their prime are liable to tragic ends.

1. VIEW OF ANTELOPE HOUSE, NATIONAL ZOOLOGICAL PARK

2. AMERICAN BISON, OR BUFFALO, IN NATIONAL ZOOLOGICAL PARK

1. OTTER AND FAMILY OF YOUNG BORN IN NATIONAL ZOOLOGICAL PARK

2. HOUSE FOR ELANDS AND MOUNTAIN SHEEP, NATIONAL ZOOLOGICAL PARK

1. CEMENT BRIDGE OVER ROCK CREEK, NATIONAL ZOOLOGICAL PARK

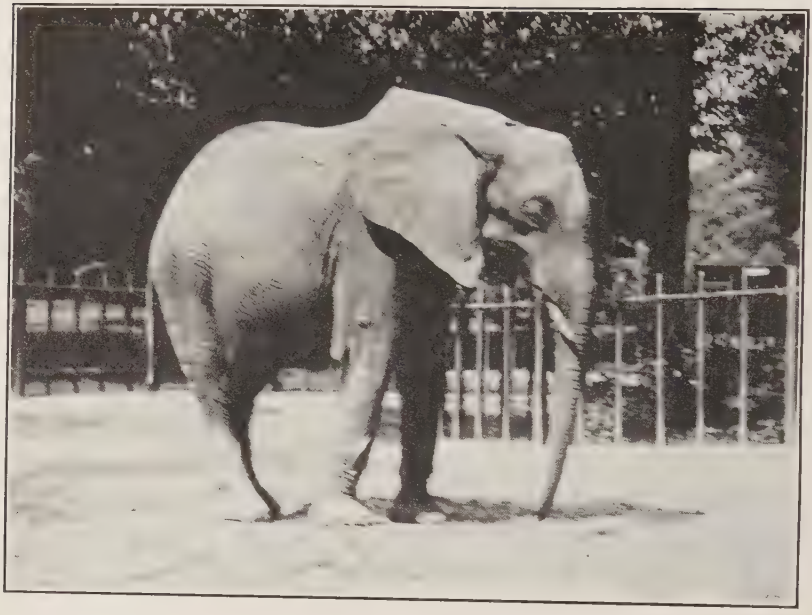
2. STONE BRIDGE OVER ROCK CREEK, NATIONAL ZOOLOGICAL PARK

1. AOUDADS, OR BARBARY SHEEP, NATIONAL ZOOLOGICAL PARK

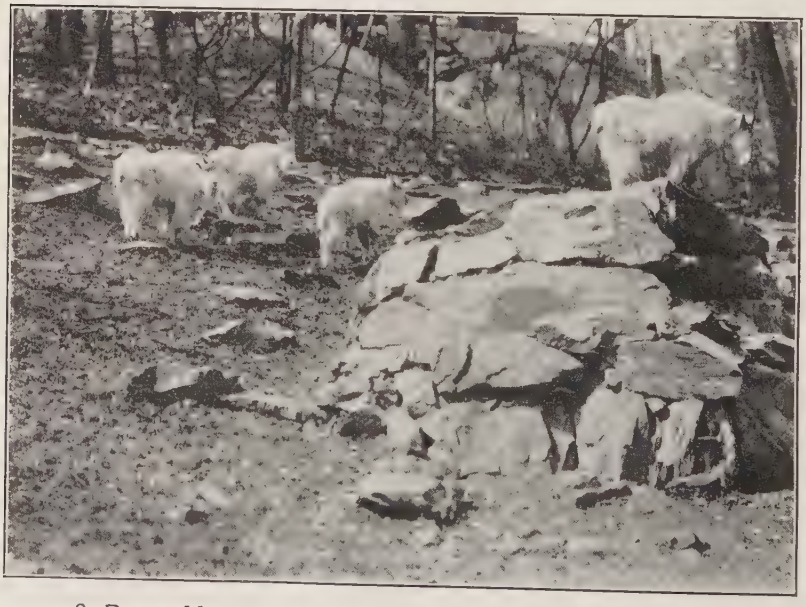
2. NEW TYPE OF SANITARY OUTDOOR CAGES, NATIONAL ZOOLOGICAL PARK

1. MONKEY HOUSE, NATIONAL ZOOLOGICAL PARK

2. GREAT FLIGHT CAGE FOR BIRDS, NATIONAL ZOOLOGICAL PARK



1. FEMALE AFRICAN ELEPHANT "JUMBINA," 12 YEARS OLD, NATIONAL ZOOLOGICAL PARK



2. ROCKY MOUNTAIN GOATS IN NATIONAL ZOOLOGICAL PARK

1. ONE OF THE CALIFORNIA CONDORS IN THE NATIONAL ZOOLOGICAL PARK

2. TRUMPETER AND WHISTLING SWANS ON THE NORTH AMERICAN WATER-FOWL LAKE, NATIONAL ZOOLOGICAL PARK

1. YOUNG ARABIAN CAMEL BORN IN THE NATIONAL ZOOLOGICAL PARK

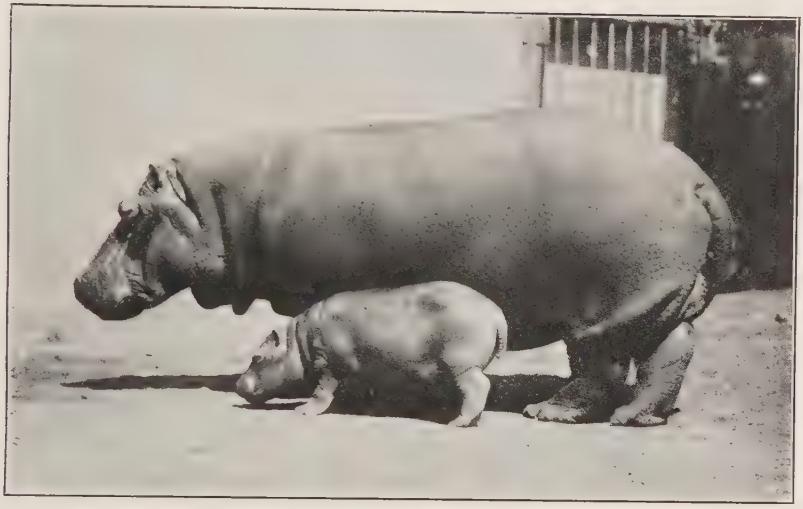
2. LLAMAS WITH YOUNG, NATIONAL ZOOLOGICAL PARK

1. EUROPEAN BROWN BEAR WITH THREE CUBS BORN IN THE NATIONAL ZOOLOGICAL PARK

2. RED KANGAROO WITH YOUNG IN POUCH, NATIONAL ZOOLOGICAL PARK

1. COLLARED PECCARY AND YOUNG BORN IN NATIONAL ZOOLOGICAL PARK

2. A GROUP OF YOUNG OSTRICHES, NATIONAL ZOOLOGICAL PARK



1. HIPPOPOTAMUS AND YOUNG BORN IN NATIONAL ZOOLOGICAL PARK

2. THE ANIMAL HOSPITAL, NATIONAL ZOOLOGICAL PARK

1. Crowned Cranes; and Young Rocky Mountain Sheep Born in the National Zoological Park

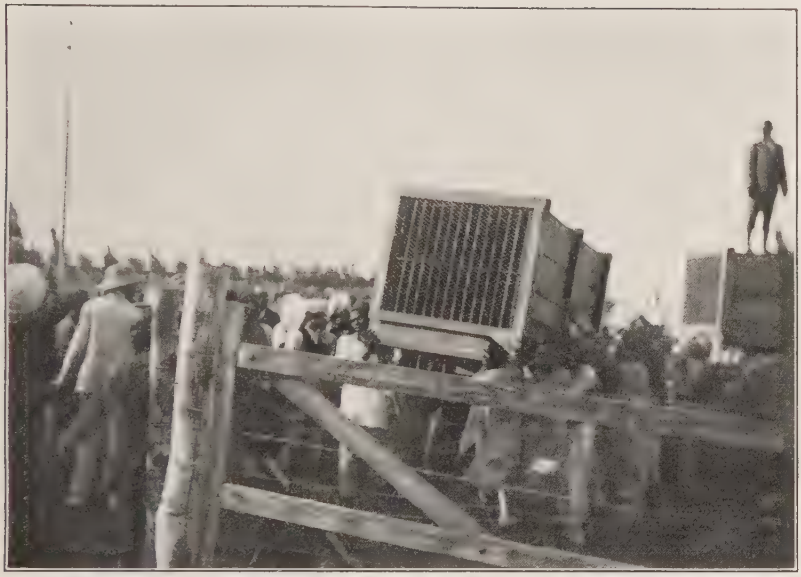
2. A Pair of Brazilian Tapirs, National Zoological Park

1. WOODLAND CARIBOU, NATIONAL ZOOLOGICAL PARK

2. PRONGHORN ANTELOPE, NATIONAL ZOOLOGICAL PARK

1. MUTE SWANS WITH YOUNG, NATIONAL ZOOLOGICAL PARK

2. STELLER'S SEA LION, NATIONAL ZOOLOGICAL PARK



1. LOADING LIONS ON THE TRAIN AT NAIROBI, EAST AFRICA, FOR SHIPMENT TO THE NATIONAL ZOOLOGICAL PARK

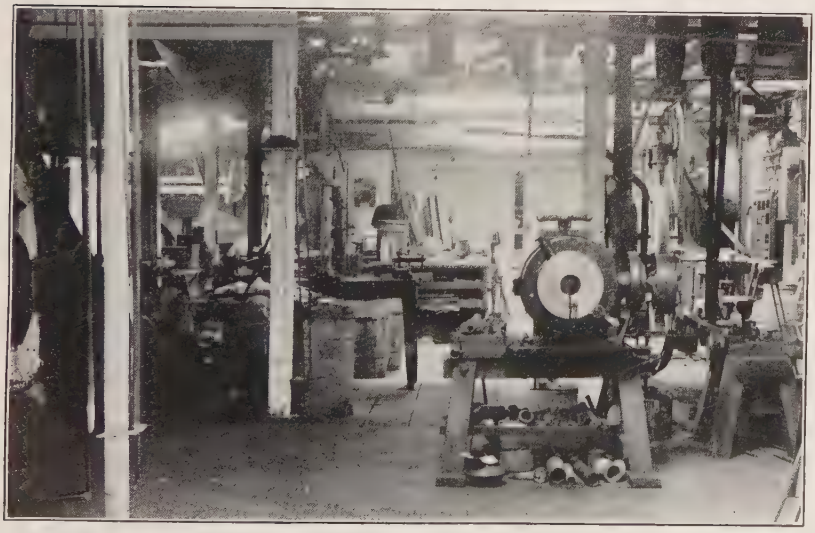
(Photograph by A. B. Baker)

2. ELEPHANT HOUSE, YARD, AND BATH, NATIONAL ZOOLOGICAL PARK

YOUNG ELEPHANTS CAPTURED IN SUMATRA AWAITING SHIPMENT TO AMERICA. THE SECOND ONE FROM THE LEFT AND THE LITTLE ONE AT EXTREME RIGHT ARE NOW IN THE NATIONAL ZOOLOGICAL PARK

(Photograph from Louis Ruhe)

1. A BUFFALO CRATED FOR SHIPMENT, NATIONAL ZOOLOGICAL PARK



2. THE MACHINE SHOP, NATIONAL ZOOLOGICAL PARK

1. ARCTIC FOX, NATIONAL ZOOLOGICAL PARK

2. CINNAMON BEAR AND HER TWO NEARLY GROWN CUBS, NATIONAL ZOOLOGICAL PARK

NESTS AND NESTING HABITS OF THE AMERICAN EAGLE[1]

By Francis H. Herrick

Western Reserve University, Cleveland, Ohio

[With 3 plates]

I

In northern Ohio the fringe of forest along the southern shore of Lake Erie has long been the haunt of the American or white-headed eagles (*Haliæetus leucocephalus*). They were here before the white man dispossessed the Indian, and here many have remained, in spite of all the changes which he has wrought in the forests and upon the shore, undismayed if not undisturbed by his incessant activities afield; until, unless an active war has been waged against them, they have come to show no fear of the once novel sights and sounds of an advancing civilization, and for the most part they have come to disregard them utterly, ever trusting to their inherent powers of circumspection for their own safety, to their physical prowess, their adaptability and to their marvelous speed in the air.

The lake country was no doubt favored by the eagles because of the almost never failing supply of fish to be found in most seasons either at the surface or stranded upon the beach, a supply now greatly augmented at certain points by rejects from the pound and gill nets of fishermen.

The favorite nesting trees of this region are the sycamore and the shellbark hickory; and that the dying or dead of these and other species are repeatedly chosen by the same pair of birds must, no doubt, be ascribed to habit, determined in the first instance by the need of a safe approach to the aerie, and of an unobstructed outlook from its spacious summit. When one of the branches which supports the nest comes to be used as a perch, the nesting scenes take

[1] Reprinted by permission from The Auk, Vol. XLI, No. 2, Apr., 1924.

The "bald" or white-headed eagle was adopted as the sign of the independence and sovereignty of the United States by vote of the National Congress on June 20, 1782. Although the golden eagle (*Aquila chrysaetos*) is also found within our limits, being now confined mainly to the territory west of the Mississippi River, it seems appropriate and would certainly be convenient to designate our national bird as "The American eagle," and to make the popular use of this term exactly discriminative of the species.

on at once a new and livelier interest; for then the birds can shift readily from nest to perch, or back again to the nest, and to have the whole family at dinner may be a daily experience. It is possible that a sound tree, when long occupied, might suffer and finally languish under the ever growing mass of vegetable decay which it is usually called upon to sustain. This was apparently the case with the nest tree at Vermilion, Ohio, about which our interest will be mainly centered in subsequent articles; though somewhat broken at the top, there was enough foliage about this great nest in 1922 to seriously hamper observations; in the following spring, to our great surprise, the flow of sap suddenly failed and, except upon a single branch at a height of barely 20 feet, the life of this tree went out. Other hickory trees in the same grove, though unencumbered, have also died, and during the spring gales of the present year many were broken or overthrown, so we can record only the fact, while the relation of cause and effect remains in doubt.

So far as I have observed, the nest tree is seldom at first completely isolated, but commonly stands on the border of woods or in an open grove, a mile or more from the lake, and it often rises to such a height as to command the entire neighborhood. I have known one instance where the surrounding timber was cut away, but a kindly farmer spared the eagles' tree, and its great aerie, borne aloft and visible for miles in certain directions, stood out like a castle on a hill.

What has just been said would not apply to island nests, and in our studies of the eagle experience is ever warning us against indulgence in the easy path of generalization; not only must we expect to find much variation in habit among different individuals, but also in the same individuals at different times, for habit in this sense is the result of experience. Most eagles are great place holders, and we have recorded the instance at Vermilion in which the same aerie has been occupied for upward of 34 years without a break, and the immediate region for nearly a century; while other individuals, bent possibly upon improving their condition with respect to the food supply, their safety or that of their aerie, seem to be constantly on the move. Thus, a pair at Danbury, Ohio, have moved three times in five years, and I have known a deserted aerie to be reclaimed after an interval of one or more years, presumably by the original owners. At Kelley's Island a number of nests are in open pastures, and in at least one instance the site is so poorly chosen as to suggest the work of inexperienced builders. On an island in the Pacific, 50 miles south of San Pedro, known as San Clemente, Breninger[2] found two ground nests of this eagle in February, 1903; they were placed

[2] Breninger, George F. San Clemente Island and Its Birds. The Auk, Vol. XXI, p. 219. Cambridge, 1904.

on either side of a deep gorge, and were said to have been used in alternation by the same birds for the space of 15 years; the one on a large rock a mile from the north end of the island then contained two eggs; while the other, on a hillside amid grass, was then in disuse; the latter was so high that a man standing beside it could not see into its shallow top.

When the site is well chosen the nest is securely held in the grasp of a number of spreading branches. Possibly any tree offering such conditions might be taken, but I have seen only the sycamore, the hickory, and the elm thus used, and the fact that a given pair of eagles will sometimes favor the same kind of tree for a number of successive nests is a strong argument for the force of habit. Where the upright branches are nearly vertical, the nest, as in that formerly at North Springfield, Ohio, gradually assumes a cylindrical form (pl. 1); where the spread is greater, the aerie takes the cup form and later that of the wineglass or tall inverted cone (pl. 2); in an exceptional case at Kelley's Island, to be later noticed, the aerie was remarkably symmetrical and in shape of a huge bowl over 7 feet in diameter (pl. 3); but it should be noted that such comparisons apply to the exterior only, since "cup" and "bowl" are here solid to nearly the brim; indeed, in certain cases no concavity exists, but the aerie is markedly convex at the top. The diameter of a new as of an old nest will depend, as I have intimated, upon the angle of divergence of its main supports, but in a number of instances observed the first year's nest measured 5 feet across the top and its height was approximately the same.

A nest of the first year consists of a great mass of sticks, gathered mainly from the ground, borne to the nest site in one or both talons by either bird, and laid individually with aid of the bill; as this mass of fagots grows, greater attention is paid to the periphery, where the coarser materials are more carefully and more effectively interlaid and adjusted; the center and interstices are filled with dead weeds, cornstalks, and stubble, with incidentally considerable earth introduced with pieces of sod and with weeds. It is no wonder that with the growth of years the core of such a structure comes to form a sodden mass of vegetable mold. The largest sticks which I have taken from different nests were a yard long and 2 inches thick, but many which I saw in a nest at Kelley's Island this summer appeared to have a length of over 6 feet. I am not yet ready to speak of the act of nest building in detail, but examination clearly indicates that such sticks are mainly gathered from the ground. The owner of the land on which the nest at North Springfield was situated told me of having seen his eagles in nesting time fly against the dead branch of a tree and, as it snapped with a sharp report,

bear it off to the aerie; if such statements are true, the eagle clasps the branch in its talons and breaks it off by sheer force as the fish hawk is known to do, an easy matter for birds of their weight and strength. The Vermilion eagles at a later phase of nest life would now and again bring in their talons a cluster of living oak twigs and lay them upon the nest, a curious habit, the meaning of which will be considered in another place.

Eagles are supposed to be mated for life, and that when one is bereft it goes in search of a new mate. So far as known its quest is invariably successful, though it may return with a bird in juvenal dress. This loss and substitution of a mate occurred at the Vermilion nest when one of the pair was shot, but this was some years ago, and the exact circumstances could not be determined. It may be doubted if either parent would desert or leave for long their young when well started on the road of development; on the other hand we might expect a lone bird to abandon its eggs per force and, if again mated, to begin a new nesting cycle upon its return; but whether this has actually happened or not can not be stated. Since at least three years are passed before acquiring the perfect coloring—white head, neck, and tail, and yellow bill—and since young birds without doubt become sexually mature the first spring after birth, one may expect to occasionally find one in brown or juvenal dress mated to a full-colored bird; and Hoxie[3] mentions a case in Chatham County, Ga., in which both birds were in immature plumage, though the female was then beginning to show distinct traces of white in the tail; the nest in this instance was in process of building on March 6, 1909, but according to this observer it did not contain young until May 17. The incubation period was given as 83 days, and the time from hatching to flight as 42 days. Fresh eggs were said to be found in that section from mid-November to late March. Two cases were also mentioned, at Savannah, in which this eagle laid a second set of eggs after having been robbed of her first; in the one instance the first set was taken on December 5, and in the other on the 12th of the same month. There is a similar record for Lincoln County, Me.,[4] where the eagles held to their aerie after being repeatedly robbed, and in all probability they made their losses good. In this instance the nest was in a tall dead pine, and what is more important it was lined with green pine boughs, the possible significance of which will be noticed at a later time. Two partially incubated eggs were taken from this nest on April 7, 1891, and three, in which the development

[3] Hoxie, W. J. Notes on the Bald Eagle in Georgia. The Auk, Vol. XXVII, p. 454. Cambridge, 1910.

[4] See The Auk, Vol. XXIII, p. 222. Cambridge, 1906.

was far advanced, on the 16th of the same month of the succeeding year. The following happened at the Vermilion nest: A collector ascended the tree and removed the first set of two slightly incubated eggs on or about March 18, 1920, after which a second set was laid and the young reared in due course. I have not yet definitely determined the exact period of incubation at Vermilion, being unwilling to interfere in any way with the process until our observations on all later phases of nest life were reasonably complete. From what was seen this year, however, I am satisfied that the incubation did not exceed four weeks.

It is commonly said that eagles, when once settled down, occupy the "same nest" year after year; it would be more exact to say that the eagle builds anew each year, but uses the old nest as a site for the new one. Like most other birds, it satisfies its building instinct at a certain time every year, but, unlike most, it is chained to a certain spot, which is its old nest. As a result of these yearly increments the eagle's aerie gradually rises in height and, since it must meet the spread of its main supports, it may increase steadily in diameter often, as we have seen, taking the form of an inverted cone or balloon, until at last the nest tree collapses under its ever increasing burden. Such a structure from the standpoint of the student, if not of the builder, is thus a compound or storied nest; it might be compared to a stack of saucers, each of which represents a "nest," or a unit which is yearly added to the pile, but becomes so completely incorporated with what precedes as to be thereafter inseparable from it.

II

Of some eight nests of the American eagle which I have examined in the south shore region of Lake Erie, two were at North Springfield, two at Danbury, and three at Kelley's Island, besides that at Vermilion, the most remarkable of them all.

While traveling on the Lake Shore Railroad some years ago I happened to notice an eagle's nest from the car window not a thousand feet from the line at a point near Girard, in Pennsylvania; as this nest appeared to be of unusual size and occupied the top of a dead truncated tree which stood quite alone, it aroused my curiosity. After learning that this great aerie had long been a landmark of that region, being well known apparently to every workman upon the road, I resolved to pay it a visit. Upon reaching Girard in the following June I found to my keen regret that the old sycamore with its famous nest had gone down in a gale of the previous winter, but from photographs[5] made before its fall (pl. 1), together with measure-

[5] By Mr. H. E. Denio, of Milesgrove, Pa.; for a series of pictures of this nest, see "The Eagle's Nest," St. Nicholas Magazine, Vol. XXIX, New York, 1902.

ments which it was then possible to secure upon the ground, I am able to give its exact dimensions. It was 9 feet in height and had a nearly uniform diameter of 6 feet; according to report it had been occupied for 15 years, and its top, as I found, had originally stood at a height of 77 feet from the ground. The nest was essentially wedged between two upright branches, though receiving some support from a smaller division of the main stem which at the base attained a diameter of 3½ feet; its two main supports were broken off at a height of 6 feet from the top of the aerie and served the eagles as favorite perches and lookout points; the nest was a great mass of wattled or intercrossed sticks, made solid with earth and the resultant decay of the annual additions of weeds, stubble, and straw.

For many years these eagles were said to have occupied a dead sycamore in the midst of woods in Milesgrove, Pa.; when this aged tree succumbed, the more famous nest, which we have described, was established in another sycamore, also dead, at North Springfield just over the line, in Ohio, in 1885; this lasted, as we have seen, 15 years, or until January, 1900. The third nest was started in the spring of that year at a point not many rods from the site of the second and again in a sycamore, but this time in a living and sound one. This tree had a girth of 12 feet at the ground and a clean straight bole without a branch for 60 feet; at this point it spread a number of strong arms which formed an all-embracing niche for a nest of great size. No doubt it was this great crotch which had attracted the eagles, though close beside it rose a stately tulip tree, the branches of which met those of the sycamore and partly overshadowed them.

Upon approaching this nest on the 8th day of June not a sound was heard for full 20 minutes, when suddenly one of the eagles appeared, whose behavior suggested the male bird, and circling overhead, began to sound his peculiar alarm, which I have heard many times since. It may be transliterated as *kar! kar! kar!* with sometimes the suggestion of a final *k* at the end of each syllable, or again as *cac-cac-cac!* Then, alighting in the topmost branch of a dead tree, he expressed his emotion in a manner characteristic of many birds even as remote of kin as the nighthawk; with depressed head and neck outstretched, with drooped and quivering wings, his mandibles would open and close with the regularity of clockwork. Dr. William L. Ralph[6] was always able to recognize the male by this alarm, the call of the female being more harsh and often broken. The female was sitting in her aerie during the time of our approach, as became evident when she suddenly left it and with protesting

[6] Bendire, Captain Charles. Life Histories of North American Birds. Smithsonian Contributions, Vol. XXVIII. Washington, 1892.

screams soared over the tree tops; neither bird would come to the nest while I was in the neighborhood. At this time there were two eaglets, in full feather but quite invisible from below, except as one would appear and shoot a white stream well over the edge of the nest. At the Vermilion nest we did not hear the alarm call after the last week of May in 1922; not once was it sounded within hearing during our long vigil beginning early in June and lasting until the flight of the young eagles in early July. Silence also seemed to be the rule during the present season, and it was possible for us to determine the female only by her slightly greater size and more sinister countenance. We noticed, however, that whenever an observer showed himself upon our platform, passed under one of the perches, or approached the observatory tree, either eagle, if present, would crane its neck in his direction, open and close the mandibles, and if uttering any sound at all, biting it off so effectually that it was scarcely audible at a distance of 80 feet.

Two nests which I examined at Danbury, on July 5, 1922, and which were occupied successively by the same pair of birds, were markedly convex at the top, but whether this peculiarity was due to a habit or whim of the builders or, as seemed more likely, to a lack of suitable supports at the margin of the nests, could not be determined. I am able to give a partial history of these nests through the efforts of Mr. W. G. Tibbels to save the eaglets from community vengeance. The farmers in their vicinity, it seems, had lost a number of their chickens and were bent on keeping the eagle population down. The first nest to be built and occupied stood at a height of about 70 feet in the top of a dead shellbark hickory on the edge of woods, about midway between Sandusky Bay and the lake; it was rather more than 6 feet tall and measured 4¾ feet across the top. Mr. Tibbels climbed to this nest at about the middle of June for three years in succession, 1919–1921, and removed the young, his plan being to hold them until they were able to fly and then release them. The old eagles, he told me, behaved in essentially the same way each time he raided their aerie; they would swoop down at him with talons extended as if about to strike, but they always swerved when 6 feet or more away and would eventually settle in the top of neighboring trees where, with opening and closing mandibles, they gave vent to their alarms. They did not leave the vicinity while he was at the nest. On one of these visits the aerie was strewn with the carcasses of muskrats, rabbits, chickens, and fish, including the half-decomposed body of a large carp; two of the muskrat skeletons carried each a steel trap, which might indicate that these rodents had been taken outside of the nesting

season, or at least not long after the beginning of March, and that the aerie served its owners as an habitual dining table.

In the spring of 1921, according to Mr. Tibbels, the Danbury eagles were seen carrying nest materials to a new site a mile away, while they continued to hold to their first nest described above; this was finally abandoned at the close of that season, probably not because of the repeated raids which had been made upon it, but rather on account of the insecurity of the nest itself, which had lost a main supporting branch. At the time of our visit it was sagging over the stump of this lost limb and appeared as if ready to topple over in the next storm. At all events the new nest was completed and occupied in the spring of 1922 upon the site which had been determined the previous year. This second nest was also in a dead hickory that stood on the border of woods and, although barely elevated above the surrounding tree tops, it afforded a good outlook. The tree was less than 2 feet in its greatest diameter and the nest, which was estimated to stand at a height of about 75 feet from the ground, was approximately 5 feet tall and would measure as much or slightly less across the top. When Mr. Tibbels climbed to another nest about the 1st of May, he found the top strongly convex, as in the former case, and three eggs lying close together in a depression that was evidently made by the laying bird. On this occasion the old eagles, contrary to what might have been expected, made no hostile demonstrations, but kept the climber in sight while they were perched in neighboring trees.

As we approached this second nest on the 5th of July, about seven weeks later, one of the old eagles stood guard above it and soon went off in silence, but a young bird that was resting or possibly feeding in the aerie itself remained until we were close upon the tree. We found that the two eaglets, which had been on the wing for upward of a week, were still in the habit of returning to the aerie either alone or in the company of their parents.

The unpopularity of these particular eagles evidently had not abated, for an attempt had been made to fire their nest tree; whether they were eventually driven out or not, I do not know, but, according to Mr. Tibbels, they again abandoned their aerie in the spring of the present year, and moving across the peninsula, settled 8 miles to the northwest at Port Clinton.

On July 2, my assistant, Mr. E. J. Humel, and I visited Kelley's Island, which lies 10 miles due north from Sandusky, and is only less famous for its eagles than for its extensive limestone quarries and its world-renowned glacial grooves. The eagles now frequent the semiwild eastern half of the island, which is 3 miles long by 2 broad. We visited three nests in the short time at our disposal and

a later and more careful search revealed no others.[7] All of the nests which we examined were said to have been recently occupied, but they were abandoned at the time of our visit and not an eagle was seen on the island. Our arrival happened to coincide with that of the well-known annual pest of mayflies or "Canada soldiers," which come suddenly, remain a week or less, and as suddenly depart. It is no exaggeration to say that, after leaving the roads, we were hampered at every step by these extraordinary creatures which covered all exposed objects; all standing room seemed to be taken on every spear of grass, on every twig and leaf; the very bark of the trees, great and small, being "furred" by them; and as we walked they swarmed up in such incredible numbers over our bodies as to almost blind us. It was difficult to keep the lens of our camera clear of them long enough to take a photograph.

All the nests which we saw were in open pastures; the first to be visited, on the northeast side of the island, stood in the top of a decrepit elm at a height of about 75 feet; it was of the cup form, perhaps 8 feet tall and 6 feet or more across the top. A farmer, engaged in spraying his grapes near by, informed us that it had been abandoned and again reoccupied the present season. Another nest, farther to the south and east, was also in a living elm, which was 12 feet in girth and stood some 1,200 feet from a roadway. It appeared to be very insecurely placed at a height of about 60 feet and was evidently a nest of the first year, measuring hardly more than 5 feet either way and remarkable only for its asymmetry and the great length of many of the sticks which entered into its mass.

The second nest that we visited, at a point a little to the south of the first, was so remarkable that the sight of it alone amply rewarded us for all our trouble and annoyance with insects. It crowns a remarkably small shellbark hickory (pl. 3), about a foot and a half in diameter at its base and living in every branch, the lowermost being within reach from the ground so that a good climber should be able to make the ascent without much difficulty and by the aid of a cord to surmount the aerie. We were told that not long ago a man had made this attempt, but was attacked so viciously that he quickly had a change of heart. This nest is remarkable for is symmetrical bowl shape, as well as for its proximity to the ground; according to our later estimates, it is 6 feet tall and over 7½ feet

[7] I visited the island again on Apr. 12–13, 1924, in company of my friend Prof. H. W. Mountcastle, who ascended the tree in which the bowl-shaped nest herein shown was placed and obtained data for the correction of our earlier estimates of its dimensions and height from the ground. At that time two of the nests were occupied, but, to our disappointment, this last and most interesting of all had been abandoned.

across the top, and a line dropped from its base to the ground measured exactly 37½ feet. It is very evident that the unusual form of this nest is due to the spread of its main supports, which diverge at an angle of 70°. It should be noticed that the top of the aerie in this instance is almost completely shaded by branches rising to a height of 10 feet or more on all sides.

The history of the Vermilion eagles, the fullest of which I have any records, and covering a period of over 80 years, is given in detail in an earlier paper.[8] During that time four nests have been occupied for varying periods in the township of Vermilion, at points a mile or more removed from the shore of the lake. The fourth and present nest (pl. 2), which has been occupied for at least 34 years, stands at a height of 81 feet, in a shellbark hickory which, as already noticed, was more or less alive up to the spring of 1923; it was 12 feet tall and 8½ feet across the top when exact measurements were made on July 20, 1922. When examined at this time, just 16 days after the young eagles were on wing, all carcasses of fish, chickens, and other animals had been removed and its inside depth did not exceed 4 or 5 inches; the eaglets, in the course of many weeks of exercise, had trodden its surface nearly flat. At that time all the surface material, to the amount of half a bushel or more, was gathered up and lowered in a sack; this was found to consist of fish and chicken bones in sparing amount, fish scales, short loose sticks such as the young eagles had often been seen to use in their play, fragments of cornstalks, clusters of oak twigs with the dried green leaves still upon them, corresponding with what we had seen the old eagles bring to their aerie, besides a miscellaneous assortment of vegetable rubbish. Underlying this loose layer was a fairly compact floor of vegetable mold, which extended some 2 or 3 feet on all sides from the center of the nest and was easily dislodged with the hand.

III

Though hoping to turn my attention to nest building and other early phases of activity another year, I will now set down in brief what happened at the Vermilion nest in the spring of 1923. When Mr. Headline and his men were building the second platform of our observatory on March 13–15, they were obliged to abandon their work for a part of the time on account of severe gales, which during that month brought down many trees in the grove and threatened that of the eagles with destruction; accordingly, we took the precaution of securing it as best we could by the aid of steel wires. The eagles were engaged in building also, but, as Mr.

[8] The Auk, Vol. XL. 1923.

Headline reported, they paid little attention to the carpenters; while one of the eagles would fly over the aerie and drop a bundle of straw, cornstalks, or stubble, which it carried in its talons, the other would dispose of it, remaining thus engaged for 15 or 20 minutes at a time; they had already built a barrier of sticks about the margin and were now laying a mattress of straw and softer materials over the center; when the carpenters finally returned to finish their work on the 20th of March, this bedding was completed, and one of the eagles, presumably the female, was sitting in its midst, though not continuously while the men were there. We infer that at least two eggs had then been laid, or were about to be laid, and allowing the eagle two or three days for sitting on the nest before actually producing an egg, the probable error as to the beginning of incubation is not likely to be greater than this either way.

When I next visited the nest with Mr. Headline on April 6 incubation was well advanced; as we proceeded down the lane and entered the grove not an eagle was to be seen, and in spite of our past experience it was impossible to repress the feeling that some mishap might have befallen eggs or birds. We had not taken many steps in the grove, however, before the male suddenly hove into view from the east, wheeled and settled on one of his habitual perches in the woods. This quickly dissipated our fears, and as we approached the nest tree a white head rose from the top of the aerie, at its very center; with the binoculars we could see that head and neck were craned in our direction, the better to follow our movements upon the ground; as we reached the observatory tree she went off silently and joined her mate on his tree-top perch. We then proceeded with our business, raising a 12-foot ladder to the upper platform and mounting it there, in the hope that by its aid we might see the eggs in place, as the eagle had left them. Since this platform rises 95 feet above the ground, and 14 feet above the level of the nest, this ladder would easily carry the eye 15 feet higher; but at even 29 feet above the top of the aerie, we could not detect the eggs within it, so completely were they concealed with the thick cover of straw and stubble. As it is a slow, difficult and rather hazardous task to climb the nest tree, we resolved to take no further risks with the eggs during the present season. While on the upper platform at this time I saw an interesting performance—the male eagle assailing the female, rising above her, striking at her with talons extended, in anything but an amorous manner, and apparently trying to induce her to return to her eggs.

On April 21, two weeks later, I found both eagles standing on their aerie, and at once concluded that the eggs had hatched; this proved to be the case, for upon again ascending to our upper platform we could see two eaglets, which from their appearance could

not have been out of the shell over three or four days, feebly raising their fluffy heads above their warm bed of straw; we could only see that they were well coated with grayish white down, and that their bills were large and by contrast very black. Close to the young and half buried in the straw lay the carcass of some animal which we could not identify, but from the deep red color of the flesh we suspected that it might be a rodent.

Although this eagle, as Audubon found by climbing repeatedly to the nest, may sit for a number of days before laying is actually begun, the incubation period could not have been far from four weeks, or approximately from March 20 to April 17. Since eaglet number one left its nest for the first time on June 27, and eaglet number two on July 1, they remained continuously in the aerie about 71 and 74 days, respectively.

IV

The Vermilion eagles appear to leave their habitual breeding and hunting grounds only when the usual food supplies give out. In ordinary seasons, according to Mr. and Mrs. Buehring, they are away only from six to eight weeks, or from mid-November to mid-January; but in the season of 1921–22, which was one of the mildest on record, they were missed for barely a fortnight in the latter part of December. In the winter of 1922–23, which continued rather mild until January, both birds remained in the neighborhood, and were even seen resting on the nest itself at the very end of December.[9] That the use of the aerie as resting place and lookout point, by force of habit, long outlasts the season of young, we know; by the same token we might expect the adult eagles to form a strong attachment to their home territory, and it may well be doubted if they ever leave it except under the pressure of necessity; but in this as in most other respects we should expect to find much individual variation, for in a bird of so great a range which covers the entire continent, the pressure referred to must be exerted in greatly varying degrees.

The young of most birds, when once out of their nest, are, as we say, "out for good." The slender thread, which binds them to their cradle, is snapped at the moment of flight; for all such the nest has suddenly lost its meaning or at least its function, and new habits at once step in to dominate their after life; moreover, it is the young, and not the nest, which is the strong magnet to which the parents are drawn. With the eagle, in this respect also, the case is somewhat different, for its young after their first flight are prone to return to their nest, and this they continue to do for a number of weeks, or for as long as they remain in the neighborhood. The adoption of a nest perch by old and young, as noticed at the

[9] As I was informed by Mrs. F. E. Ranney.

beginning of this paper, virtually introduces a new element into nest life, for it alters the behavior of the adults, and tends to prolong the time which the young spend at the aerie, as will be fully explained at a later time.

So far as is known, young eagles are never permitted to use the home territory for breeding purposes unless by chance, at some future time, one should become mated to a parent; according to the testimony of other observers, after three weeks or more of semi-independence, they are effectually driven off by the old birds, when their powers of flight and of securing their own food have become well established.

To return to the first Danbury nest: One of the three eaglets, taken by Mr. Tibbels in June, 1921, was possibly killed and was certainly eaten by the other two; at the time of our visit one of the survivors, though 13 months old, had never acquired the necessary coordination for independent flight, and was still a captive. Anyone who was confirmed in the belief that the emblem of his country was in real life a timid creature and a coward at heart would have revised his opinions after having attempted to approach and manage this bird. When, after cautious manipulation, it was finally released and set free upon the grass, it would endeavor to escape by making long leaps and flapping its powerful wings, but it never seemed able to rise much above the ground. When it was headed off and frustrated in these attempts it would rush swiftly at its assailant, endeavoring to strike with its extended talons, and at the same time to deliver swift blows with the wrists of its wings; when too hard pressed, it would throw itself back, and with erected head feathers and open mandibles, like a hawk in a similar predicament, it would strike fiercely with both feet.

V

As regards the reputed timidity or cowardice of the eagle, or indeed any other animal, it is impossible to speak with any degree of fairness without due consideration of individual differences, as well as of differences in the same individual under different conditions. Probably few people would care to meet a lion in the open, particularly if unprepared for such an encounter; yet a recent traveler, who walked 3,000 miles across tropical Africa, from coast to coast, has declared that the "king of beasts" is "a terrible coward, unless it is starving or has been injured." "I have seen lions," he is reported to have said, "face to face, and the beasts have raced away in terror." The difficulty with the lion, as with the eagle, is in knowing whether the interview has been correctly timed.

Fear is an instinct which nature has bestowed rather freely for the protection of the individual and the preservation of the race:

it often waxes or wanes, according to rather complex conditions, being frequently suppressed by any stronger instinct in those animals usually regarded as timid; in birds it is commonly suppressed by the instinct of guarding and pugnacity, which in many species rises during the period of incubation, and like a fever, reaches a climax not long after the young are hatched, and then gradually subsides. Accordingly a "timid" animal under the spur of a single instinct may at times become very bold, only to revert to its former state.

In the case of the eagles, as in so many other instances, this is further complicated by individual experience, for, in settled communities where such birds do not always escape persecution, great caution is often acquired; and their survival under difficult conditions shows that it stands them in good stead. The presence or absence of fear is thus clearly the resultant of many factors, of which individual experience is an important variable. Any climber who invades the eagle's aerie, unprepared for an attack, especially if the nest is placed low and in wild country, is liable to meet with a surprise. At times the intruder has been badly frightened, and fortunate in having only his hat snatched from his head;[10] at others, perhaps, he has been menaced only, but at too close quarters for personal comfort; again no hostile demonstrations whatever may be made. There are always one or more independent and indeterminate variable factors to be reckoned with, and the issue will depend on the character and experience of the individual bird.

Captain Bendire[11] has recorded the experience of Dr. William L. Ralph on the Indian River, Fla., which furnishes an interesting commentary on what has just been said. This region, long famed for its bird life, was described as a paradise for the eagle, at the time of his visit in February, 1886, when with the aid of an assistant he found nearly 100 occupied nests; most of these were in pine trees, "generally the highest and thickest that the birds could find," and usually at a height of 50 or 60 feet, the extremes met with at that point being 75 and 30 feet. Doctor Ralph could recall but one instance of eagles attacking anyone; this was at a nest containing two young but a few hours old and built in a large pine at Crescent

[10] Auk, Vol. XXI, p. 220. The eagles at the San Clemente Island nest, to which we have already referred, were said to have had a bad reputation for viciousness. One season at sheep-shearing time, according to this writer, an employee of the wool company attempted to ride to the edge of the barranca and take a look at the young eagles in their rock nest; as he did so one of the old eagles swooped down upon him and snatched his hat from his head, and flying off with it dropped it into the sea. At the time of his visit the writer quoted approached the nest of the same bird and took a position close to the edge of the abyss, gun in hand. He was accompanied by a small dog, which crouched in terror beside him as he sat on the ground; in a moment one of the eagles swept down upon him and came within a foot of striking him in the face.

[11] Life Histories of North American Birds, pp. 276–278.

Lake, where the birds would swoop down and almost strike the head of his climber, and were so very savage that one of his party became frightened, and, thinking that they might injure him, shot the male, which was the fiercer of the two.

The same writer has given an interesting account by Capt. B. F. Goss of two nests of the eagle on small islands in Nueces Bay, near Corpus Christi, Tex.; one of these, thought to be the work of an inexperienced bird, was on an islet which did not rise over 2 feet above high water. and was little more than a sand reef; the nest "consisted simply of a few sticks laid on the bare ground, not enough to make a single tier even, and these were covered with bones, feathers, and fish scales." The other nest, on an island but little larger and bearing a small solitary tree, rose "like a monument" out of the water and was visible for miles. "It was built with surprising regularity, appeared to be a perfect circle, and the sides smooth and almost perpendicular. It was built of sticks, and sloped slightly toward the center," where he said an eaglet sat and viciously snapped at him as he peered over the edge. Both parent birds, he adds, "attacked us with great fury, screaming and striking at us with their talons." Later when an assistant was taking the eggs from a tree nest, he continues: "he was set upon by both the eagles, and if he had not had a good stick with which to defend himself I feel sure they would have struck him."

Precisely the same kind of variability which we have noticed in the eagle, and apparently due to the same cause, may be seen in the behavior of a robin, or even of a bluebird, under similar conditions. Who would expect the ordinarily timid bluebird to attack a person who approached its nest at any time or under any conditions? Yet, I have known a male of this serene and gentle species to drive straight at the head of an intruder, and with such speed and fiery pugnacity that he involuntarily threw up his hands.

The Vermilion eagles were constantly pestered by one or more kingbirds whenever, upon approaching or leaving the aerie, they crossed their preserves. It is a familiar sight to see the doughty kingbird pursuing an eagle, hawk, or crow, now and again darting at them, pecking at their head or back and driving them from their territory. The Vermilion kingbirds would pursue their supposititious enemy up to the nest tree, and even alight upon its branches, and there continue for some minutes their harsh notes of protest close to the aerie. More than once during the present season I saw one and sometimes two of these plucky birds follow an old eagle to its tall perch, alight just above it, and as the spirit moved, dart with vim at the greater tyrant sitting in unconcern but a few feet away; at every lunge of the little kingbird the old eagle seemed

very much bored; with the glasses I could see that his mandibles opened just a little at each thrust. In all such cases the eagle can well afford to adopt a policy of indifference; but when a small hawk at Vermilion this year tried the same tactics it met with a quick surprise, for after dodging a number of times, the eagle opened its talons and with one thrust suddenly stopped the game and barely missed the hawk. Under certain conditions the eagle, as already intimated, may appear to be wary, suspicious, and timid to the last degree, but, as we have also seen, such conditions do not always prevail. Both adult and young birds, when hard pressed on the ground, or for any cause unable to fly, can put up a stiff fight against any assailant.

NEST OF AMERICAN EAGLE, CYLINDER FORM, IN DEAD SYCAMORE, 77 FEET FROM GROUND. NORTH SPRINGFIELD, OHIO. OCCUPIED 1885–1900

NEST OF AMERICAN EAGLE, WINEGLASS FORM, 81 FEET FROM GROUND, APRIL 21, 1923

Photographed from platform at height of 85 feet

NEST OF AMERICAN EAGLE, BOWL FORM, IN HICKORY, ABOUT 37½ FEET FROM GROUND. KELLYS ISLAND, OHIO, JULY 2, 1923

THE BREEDING PLACES OF THE EEL[1]

By Johs. Schmidt, Ph. D., D. Sc.

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[With 7 plates]

The problem of the propagation and breeding places of the common or fresh-water eel is one of great antiquity; from the days of Aristotle naturalists have occupied themselves therewith, and in certain regions of Europe it has exercised popular imagination to a remarkable degree. It is only during the last three decades, however, that any real results have been attained.

It has long been known that the full-grown eels move down in the autumn from their rivers and lakes to the sea; the most important eel fisheries, indeed, are based upon this seaward migration. The eels do not return again from the sea, but in early spring there appear on the coasts myriads of small young eels, eagerly seeking their way up to fresh water. These eel fry are known in most countries of Europe, and occur in some parts in such quantities as to form the object of a particular industry; for instance, in the River Severn in England, where they are known as "elvers." Until 1896, the elver stage was the earliest stage of development in which the eel was known on the shores of Europe, and it was generally supposed that the elvers arriving in the spring were the offspring of the eels which had migrated during the previous autumn. They are not, however, altogether minute, like the newly hatched larva of a cod or herring; on the contrary, they are no less than 6–7 cm. in length.

We know then that the old eels vanish from our ken into the sea, and that the sea sends us in return innumerable hosts of elvers. But whither have they wandered, these old eels, and whence have

[1] Reprinted by permission from Philosophical Transactions of the Royal Society of London, Ser. B, vol. 211, pp. 179–208. The present paper, however, is not an exact copy of the one published in the Philosophical Transactions. In addition to the postscript, which is new, various additions have been made, as, for instance, the inclusion of further data from the material collected on the cruises of the two *Danas* in 1920–1922. The work on this material is still not completed. Also, 10 figures have been added which do not appear in the paper in Philosophical Transactions, viz, text Figures 3, 13, 14, 15, and Plates 1, 2, 7, as well as text Figures 6, 7, and Plate 6, Figure 1. The first seven of these are original; the last three (text Figures 6, 7, and Plate 6, Figure 1) have been previously published in other papers of mine.

the elvers come? And what are the still younger stages like, which precede the "elver" stage in the development of the eel? It is such problems as these that constitute the "eel question."

The earliest possibilty of attacking this ancient problem scientifically was afforded by the Italians Grassi and Calandruccio, of whom the former published in 1896, in the "Proceedings of the Royal Society of London," a report of their investigations at Messina, entitled: "The Reproduction and Metamorphosis of the Common Eel (*Anguilla vulgaris*)."

Grassi and Calandruccio found that the elver stage is preceded by a larval stage, inasmuch as they were able to show that the little fish from the Straits of Messina, described by Kaup in 1856 as *Leptocephalus brevirostris*, is not an independent species, but the larva of the eel. The larva is leaf-shaped, transparent as glass, and about 7½ cm. in length. By a process of metamorphosis it is transformed into the eel-shaped elver, a reduction in both height and length taking place.

This Italian discovery was of great importance; we had now learned to know a stage still younger than the elver, and it did not seem difficult from this to infer the remainder of the life-history of the eel. Grassi was therefore justified in assuming that he had been able "to dispel, in the most important points, the great mystery which has hitherto surrounded the reproduction and the development of the common eel (*Anguilla vulgaris*)" (loc. cit., p. 261). Even after the discovery of the larva, however, certain points still seemed vague; one might yet ask, for instance: (1) Why were not the larvæ, like the elvers, found promiscuously about the shores of Europe, but only in the waters of Southern Italy, especially the Straits of Messina; and (2) why should we find in that water, not minute, newly-hatched larvæ, but only specimens already fully grown, or nearly so, of about 7 cm. in length?

Briefly, Grassi conceived the circumstances to be as follows: The breeding grounds of the eel lie in the great depths of the sea—in the abyssal region—which in the Mediterranean is not far from the shores. In these depths the ova, suspended in the water, are developed, and here the larvæ live, normally without rising to the upper water layers. The Straits of Messina, however, form an exception. There are some peculiar currents here, that "tear up the deep-sea bottom, which everywhere else is inaccessible" (loc. cit., p. 268); hence, it is just in the Straits of Messina that these larvæ are brought to the surface and come under observation.

This, roughly speaking, was the state of the eel question at the commencement of the present century. In the year 1904 I was led by chance to touch upon it myself. My very first investigations confirmed in every respect the Italian discovery of the eel larva and its

transformation into the elver. I have not been able, however, to confirm Grassi's theory as to the origin, manner of life, and age, of the larvæ. Still, as I have said before, that theory might well appear justified from the state of things at the time it was first advanced.

The Danish eel investigations were commenced, as mentioned, in 1904. I was then on board the research steamer *Thor*, engaged on fishery investigations in the Iceland and Faroe waters, according to the program of the International Council for the Study of the Sea. In May, 1904, after towing a Petersen's young-fish trawl near the surface of the water, west of the Faroes, it was found, on examining the contents of the net, that in addition to various other forms of pelagic life, we had also captured a specimen of *Leptocephalus brevirostris*, 7½ cm. long.

Thus the larva of our eel was for the first time found outside the Mediterranean. And the find, which was followed in the same year by another, made by Mr. Farran from the steamship *Helga*, off the west coast of Ireland, afforded a starting point for future investigations. Owing to various circumstances it came about that Denmark, a country where eel fishing is a specially important industry, was accorded the task of prosecuting the investigations further, and it fell to my lot to take charge of the work.

I had little idea at the time of the extraordinary difficulties which the task was to present, both in regard to procuring the most necessary observations and in respect of their interpretation. Our work on these eel investigations has now extended some seventeen or eighteen years, with a lengthy interruption occasioned by the recent war. The task was found to grow in extent year by year, to a degree we had never dreamed of; in fact, we have been obliged, in order to procure the necessary survey material, to make cruises of investigation ranging from America to Egypt, from Iceland to the Cape Verde Islands. And this work has been handicapped throughout by lack of suitable vessels and equipment and by shortage of funds; indeed, had it not been for the private support afforded from numerous different sources, we should have had to relinquish the task long since.

I propose now to give a brief survey of the results attained. They are based on dry figures, representing measurements and other observations; yet, taken in conjunction, they give us at least the outline of a life history which in point of interest is, I think, hardly surpassed by that of any other species in the animal kingdom.

In 1905, then, systematic investigations into the life history of the eel were included in the Danish program. The researches we have carried out since that date fall into two groups: (1) Investigations at sea; and (2) investigations in the laboratory.

The aim of the former was to obtain a survey of the breeding grounds of the eel, similar to that I had made of the breeding places of the Gadoids in the Atlantic from Iceland to Spain,[2] and the starting point in this case was the find, already mentioned, of a full-grown eel larva west of the Faroes in 1904. We hoped by tracking down the larvæ in ever younger stages to be able to chart the area or areas where the eel first enters on its existence and at the same time to determine the rate of growth of the larvæ and thereby the age of the elvers which appear on the shores of Europe in the spring.

The second group of investigations was, in contrast to the first, carried out on land in the laboratory. It consisted of a statistical

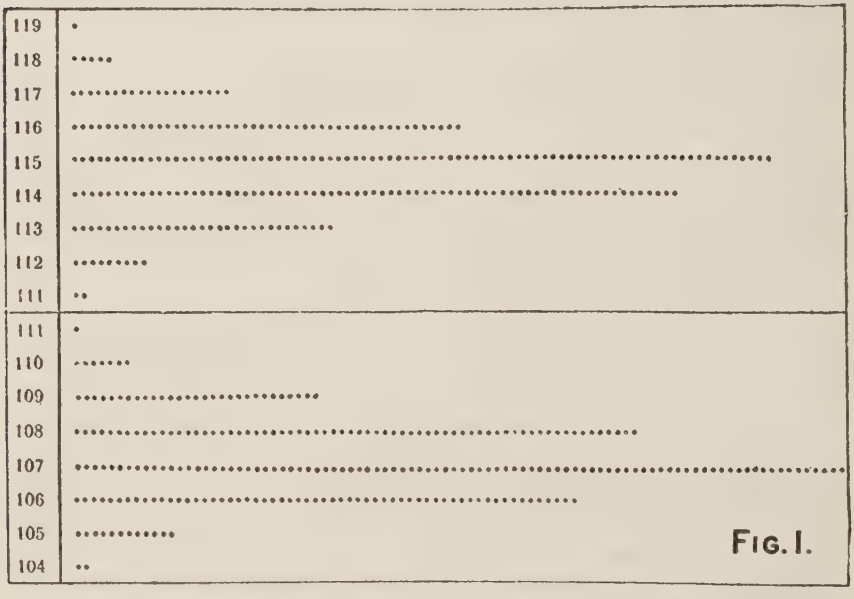


FIG. 1.—European eel (*Anguilla vulgaris*) and American eel (*Anguilla rostrata*)

Number of vertebræ in 266 eels from Denmark (*Anguilla vulgaris*, top graph) and in 266 eels from Massachusetts, U. S. A. (*Anguilla rostrata*, lower graph).

examination of samples of eels from the greater part of the Atlantic area, where fresh-water eels occur. The samples contained as a rule some 200 specimens, and the number of various organs, such as vertebræ and fin-rays, was determined in all individuals. I have published detailed reports of the results of this statistical investigation, and to these I must refer.[3] It must here suffice to lay down the fact

[2] "The Distribution of the Pelagic Fry and the Spawning Regions of the Gadoids in the North Atlantic from Iceland to Spain" (Rapports et Procès-Verbaux du Conseil International pour l'Exploration de la Mer, vol. 10, Copenhagen, 1909).

[3] "First Report on Eel Investigations" and "Second Report on Eel Investigations" ("Rapports et Procès-Verbaux du Conseil International pour l'Exploration de la Mer," vol. 18, 1913, and vol. 23, 1915); further, "On the Classification of the Fresh-Water Eels (*Anguilla*)" ("Meddelelser fra Kommissionen for Havundersögelser, Serie Fiskeri," vol. 4, no. 7, Copenhagen, 1914).

1. "THOR" (200 TONS), 1903–1910

2. "MARGRETHE" (90 TONS), 1913

Two of the four Research ships employed for the Danish eel investigations, 1903–1922

1. "DANA I" (550 TONS), 1920–21

2. "DANA II" (360 TONS), 1921–22

Two of the four Research ships employed for the Danish eel investigations, 1903-1922

that only two species of fresh-water eels could be shown to exist in the Atlantic area: A western, *Anguilla rostrata*, which is met with in the West Indies and northward of there in America and Southwest Greenland, and an eastern *Anguilla vulgaris*, which is distributed throughout Northern and Western Europe, the Mediterranean countries, and the islands of the Atlantic from Iceland to the Canaries (figs. 6 and 15). The eels found in the Azores are also *Anguilla vulgaris*, whereas the eels of Bermuda belong to *Anguilla rostrata*. In externals the two species are hardly distinguishable one from another, but certain numerical characters afford a means. The number of vertebræ in particular is a valuable character, *Anguilla vulgaris* having on an average about seven and a half more vertebræ than the American eel (*ca.* 114.7 against *ca.* 107.2—*cf.* fig. 1). If we take the trouble of counting the vertebræ it will be only a very few specimens per thousand which can not be referred with certainty to the one or the other of the two species. This fact has proved of great importance in the investigations at sea, since it was found that the larvæ of the European and of the American eel are mingled together in certain areas of the ocean.

In spite of the enormous area of the European eel, statistical investigations failed to demonstrate the existence of local races, as has been done with so many other species of fishes. All the samples, from Iceland to Madeira and from Cyprus to the Azores, yielded the same average values for the characters under consideration.

As will be seen from the following, this is entirely in agreement with the result of our work at sea.

The investigations made at sea fall naturally into two groups: (1) those carried out from the State-owned steamship *Thor*, which was equipped for marine research, during the years 1903–1910. These investigations, the general purpose of which was to study the reproduction and breeding grounds of the principal food fishes, were made in Danish waters, in the North Sea, and in the Norwegian Sea, in the Atlantic off the West Coast of Europe from Iceland to Morocco, and in the Mediterranean. (2) Investigations in the open Atlantic, carried out in 1911–1921, but with a lengthy interruption occasioned by the war. For these we were unable to use the *Thor*, her radius of action being too small. They were made from numerous Danish vessels on Transatlantic routes, with no equipment for marine research, and no experts to assist with the work, but furnished only with a net, and with instructions drawn up by myself. Though naturally of a very casual nature, restricted as they were to the course of the vessel in each particular case, these investigations have nevertheless yielded important results, and hearty thanks are due

the Danish seamen who contributed thereto. On some few occasions we were able to work more systematically and with the assistance of our own staff, as for instance in 1913, with the schooner *Margrethe* belonging to the Vendsyssel Packing Co., and in 1920 and 1921, with the schooner *Dana*, owned by the East Asiatic Co. In both these cases, despite the fact that the vessels had not the special equipment of the *Thor*, important results were obtained, and the owners, who generously placed them at our disposal for the work, have highly deserved the thanks of science. In 1921 and 1922 further investigations were carried out from the new State-owned research steamer *Dana II* (plate 2). Figure 3 shows a selection of the Danish stations, 1903–1922.

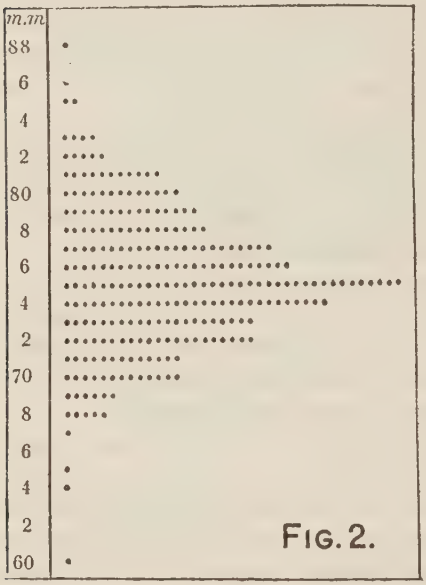


FIG. 2.—European eel (*Anguilla vulgaris*) Sizes of larvæ, II-group, at stations southwest of Ireland; *Thor*, June, 1905. Lengths in millimeters.

I will now give an account of our investigations at sea, touching very lightly upon the earlier ones, which are dealt with in detail in the reports already published.

Following on cruises made in 1903–1905 with the *Thor*, I was able to show (1906)[4] that full-grown eel larvæ were found in quantities in the Atlantic west of Europe throughout the entire range from the Faroes to Brittany, west of the 1,000 meter line. They were, however, not found east of this line; i. e., not over the coastal banks, nor in the North Sea, the English Channel, the Baltic, etc. In June, 1905, the larvæ were full grown, averaging 75 mm. in length (cf. fig. 2). They occurred pelagically in the upper water-layers, and were all unmetamorphosed. From these investigations I was able to conclude that all the eels of Northern and Western Europe come from the Atlantic, and that they come from the sea beyond the coastal banks. It was thus evident that the eel—as also, by way, the conger—occupies an exceptional position among food fishes, inasmuch as I had been able to show that the minute larvæ of most of these species belonged to the coastal banks west of the shores of

[4] "Contributions to the Life History of the Eel (*Anguilla vulgaris*)," ("Rapports et Procès-Verbaux du Conseil International pour l'Exploration de la Mer," vol. 5, Copenhagen, 1906).

Europe, and were not met with farther out. Closer study of the great elver fisheries of Western Europe (Bristol Channel, west of France and north of Spain) supported to a high degree the conclusions I had formed as to the Atlantic origin of the eel, and I was able to point out that both the Bristol Channel and the Bay of Biscay served, practically speaking, as two enormous wing nets or funnels,

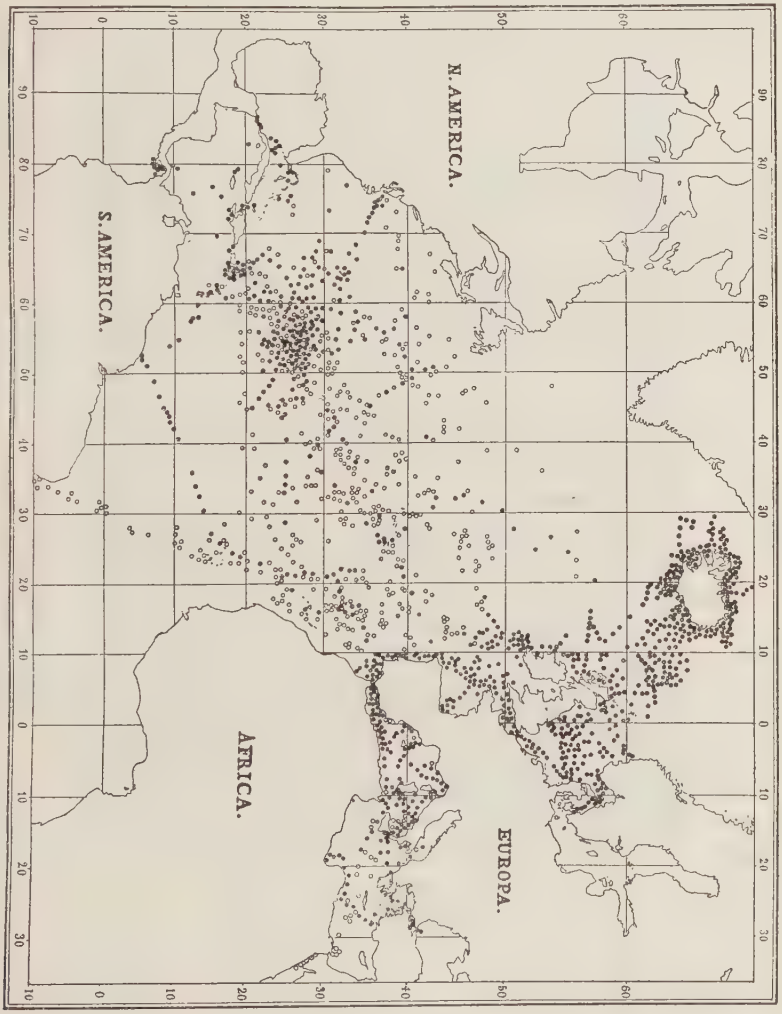


FIG. 3.—Selection of the Danish stations, 1903–1922

● Stations made by research ships. ○ Stations made by other ships.

which, facing west, would be specially calculated to pick up the eel fry coming from the Atlantic.

In 1906 we made two cruises with the *Thor* in the Atlantic, one in the spring and another in the autumn. On both these cruises full-grown larvæ were found in great numbers west of Europe, but in spring and early summer none of them had entered upon meta-

morphosis, whereas in August and September the majority were undergoing the process. It appears, then, that there is a certain periodicity in the occurrence of the larvæ; the full-grown larval stages are met with in spring and early summer, metamorphosis takes place in the autumn, and the elvers appear in winter and spring. With the abundance of material at my disposal, I found occasion to make a closer study of the metamorphosis, and was able, by means of numerous measurements, to ascertain that the larvæ, during the process of metamorphosis, are reduced in length about 1 cm., from about 75 mm. in June, 1905, to about 66 mm. in May, 1906, and in weight to less than a quarter of that before metamorphosis (pl. 3). The fully metamorphosed small eels, averaging about 6½ cm. in length, which occur in Europe in early summer, must, therefore, be presumed to be about a year older than the larvæ found at the same time in the Atlantic west of Europe, which are on an average about 7½ cm. long.

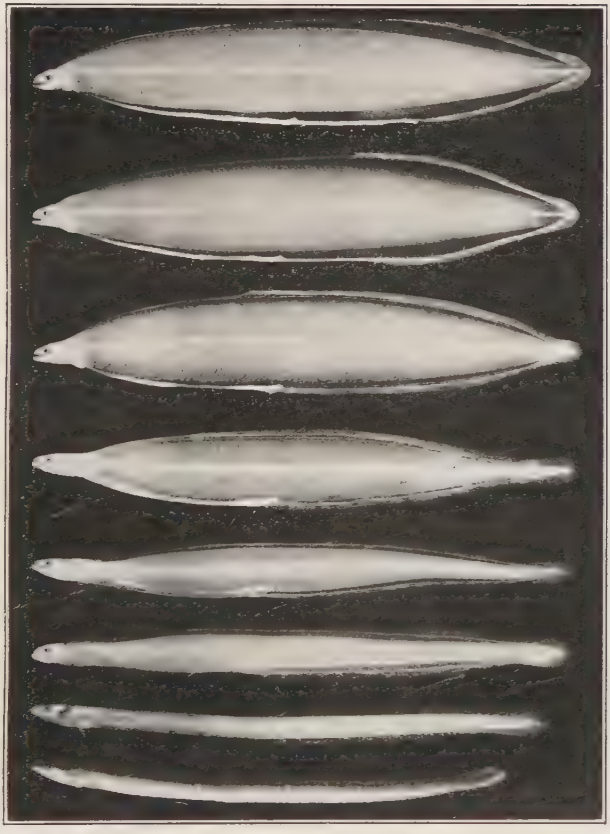
Our investigations in 1906 to the west of France showed that the larvæ occurred even over the greatest depths, over 5,000 meters; we found, moreover, that they were always distributed in a particular manner, the specimens which had not yet commenced metamorphosis being taken farther from the coastal banks than the older ones, which were undergoing the process. This led me to point out the probability that the breeding grounds of the eel were situated out in the ocean far from the coasts (1909) [5] a supposition which was to be further supported in the very next year after it had been advanced. by the appearance of new material of eel larvæ from the open Atlantic.

In a study published almost at the same time (1909) [6] on the "Distribution of the Fresh-water Eels throughout the World," I drew attention to the fact that the distribution of the eels in the Atlantic area distinctly coincides with the periphery of the great anticyclonic circulation of the water masses in the North Atlantic.

The new material referred to—eel larvæ from the open Atlantic Ocean—was derived, partly from the cruise of the Norwegian steamship *M. Sars* in the Atlantic, June–July, 1910, partly from some old collections of Leptocephali which had lain for many years unexamined at the Zoological Museum in Copenhagen. Before proceeding to this new material, I would call to mind that the eel larvæ—nearly 800 in all—which I had taken on board the *Thor* in 1905 and 1906 from the waters west of Europe, averaged about 7½ cm. in length. The largest measured 88 mm. and the smallest 60 mm. (see graph, fig. 2,

[5] "Remarks on the Metamorphosis and Distribution of the Larvæ of the Eel (*Anguilla vulgaris*)" ("Meddelelser fra Kommissionen for Havundersögelser, Serie Fiskeri," Vol. III, No. 3, Copenhagen, 1909).

[6] "On the Distribution of the Fresh-Water Eels (*Anguilla*) throughout the World" (*ibid.*, No. 7, 1909).



EUROPEAN EEL (ANGUILLA VULGARIS

METAMORPHOSIS OF LARVAE

The top specimen is a full-grown larva before metamorphosis, the two lower ones are elvers. Atlantic West of British Isles (the elvers from Danish waters). Natural size

p. 284). As to determining the age of these larvæ there was nothing of any certainty to go upon.

A highly interesting and suggestive article on the eel larvæ from the cruise of the *M. Sars*, by J. Hjort, appeared in Nature, 1910 ("Eel Larvæ from the Central Atlantic").[7] From this it appeared that forty-four eel larvæ were taken during the cruise, twenty-three to the west of Europe (north of 40° N., east of 30° W.), and twenty-one south and west of the Azores. The former ranged from 6½ to 8 cm. in length, and were thus of the same size as those I had taken on board the *Thor*. The rest, however, were considerably smaller, viz, 4–6 cm. long (one was 41 mm., three were close on 5 cm., and the remainder between 5 and 6 cm.). The smaller larvæ were taken at five stations situated between lat. 31° and 40° N. and between long. 30° and 48° W. According to Hjort's interpretation, the twenty-one smaller larvæ represent the young of that year (the O group), the larger ones those of the previous year (the I group). This being so, the first-year larvæ should by June be 5–5½ cm. long, and the full-grown larvæ of about 7½ cm. length should be about a year older. Without venturing to assert anything definite on the basis of so small a material, Hjort surmised that the breeding grounds of the eel might be in the Central Atlantic, between the Azores and Bermuda.

The eel larvæ which, as mentioned above, I found among some old collections of Leptocephali in the Zoological Museum, Copenhagen, had been procured by the Danish Capt. A. Andrea, a zealous collector of pelagic fauna, somewhere about 1865. There were only three specimens, of which one, taken near Florida Strait, proved to belong to the American species, the two others being larvæ of *Anguilla vulgaris*. The smaller of these measured 41 mm. and was taken in the vicinity of Madeira (lat. 34° 20′ N., long. 18° 30′ W.); the larger, 53 mm. in length, was found considerable farther west, lat. about 30° N., long. about 32° W.

A comparison of these two stations with the five from the *M. Sars*, did not make it easier to determine the origin of the larvae; rather, indeed, the reverse. The two smallest extant specimens, both 41mm. in length, were taken at long. 48° W. (Hjort) and long. 18° 30′ W. (Andrea) respectively; that is to say, at a distance of about 1,500 miles one from another. If these two larvæ were in the first year, and had not moved any great distance from the spot where they came into the world, this would mean that the breeding grounds of the eel embraced the entire eastern half of the Atlantic south of the Azores. Or did they, on the other hand, indicate that there were several distinct breeding-grounds, so that for instance the eels of the

[7] The same material was later dealt with by E. Lea, in "Murænoid Larvæ from the "Michael Sars" North Atlantic Deep-Sea Expedition, 1910" (Bergen, 1913).

Azores had theirs in one place and those of Madeira in another? If this were so, then where were the first-year larvæ of the enormous hosts of eels from the Continent of Europe? For it must be remembered that the Norwegian expedition with its effective fishing apparatus had taken comparatively very few larvæ of the smaller group, while Captain Andrea's large collection of Leptocephali contained but two specimens of the European eel. And, finally, there was the natural question: how old were the smallest larvæ, with their length of just over 4 cm. This question was obviously of great importance, since if the larvæ were some few months old, they might have been carried great distances during that time by the ocean currents, and in such cases it would be impossible to determine, for instance, whether the larvæ found south of the Azores had originally come from somewhere farther to the east or somewhere farther west.

Considering these points, I perceived that if the problem were to be solved in anything like a satisfactory manner it would be necessary to ascertain, not only where the youngest larvæ were to be found, but also where they were not. Until a comprehensive survey had been obtained as to the distribution and respective density of the various sizes of larvæ in all parts of the sea, it would hardly be possible to form definite conclusions as to the origin of the eels of our European Continent. The task was thus one of enormous dimensions, albeit with the consolation that the South Atlantic might be disregarded as being devoid of any representative of the genus *Anguilla*, a fact which I had been able to prove in my previously mentioned work on the distribution of this genus throughout the world (1909, loc. cit.).

In order to proceed further, then, it was evidently necessary to procure observations from the greatest possible area of the North Atlantic. As I have already stated, the *Thor* was useless for such work as this; I had, therefore, to endeavor to procure the requisite material by other means. In pursuance of the project, application was made from time to time to one and another of the Danish shipowning companies with vessels sailing regularly on trans-Atlantic routes, requesting that the ships might occasionally be allowed to draw a pelagic net for half an hour, and send in the resulting captures for investigation. Our request was on the whole very courteously complied with, and during the years 1911–1915 hauls were made at about 550 "stations" by 23 different vessels, steamers, and sailing ships, of Danish nationality, one of them belonging to the Danish royal navy. A chart of the stations[8] shows that they are

[8] "Stations in the Atlantic, etc.," with two charts and introductory remarks ("Meddelelser fra Kommissionen for Havundersögelser, Serie Fiskeri," vol. 5, no. 7, Copenhagen, 1919).

well distributed throughout the North Atlantic area. I may state at once, that the yield of larvæ of the European eel amounted in all to 120. This represents about one larva for every fourth or fifth station, a result which must be considered satisfactory in view of the highly primitive equipment, the short hauls, and the fact that a great number of the stations were in areas where eel larvæ do not occur.

During the first two years (1911–12) the collections of material made were chiefly from vessels sailing between the English Channel and the West Indies, but the yield was generally poor, three larvæ from one station being the highest. An encouraging feature, however, was the finding of a larva only 34 mm. in length at 25° N., 51° W., both from the fact that the previous minimum record (41 mm.) was thereby beaten, and also because the locality of the find suggested a place of origin even more to the south and west than we had hitherto been warranted in imagining. The material, however, was still too small and too sparsely distributed to give us the distinct indication we desired; indeed it is hardly too much to say that with each new observation a new problem arose, demanding a solution of itself, without otherwise contributing to the elucidation of the matter as a whole. Consequently, when, in 1912, I published my last report of the investigations at sea [9] I was obliged to express myself with the greatest reserve on the question of the breeding grounds of the eel, despite the fact that the finds of larvæ in the open Atlantic Ocean had considerably increased in number as shown in the chart, Plate VI, *loc. cit.*, 1912. In a summary which appeared in Nature for August 22, 1912, I summed up the position as follows: "We can not say as yet where exactly the spawning takes place, and but little more than that the spawning places must lie in the Atlantic beyond the continental slope, and that they must lie in the northern Atlantic." There was one point in particular which made the matter difficult. As already mentioned the *M. Sars* had in the month of June found a score of larvæ, 4 to 6 cm. in length, which were classed by Hjort as belonging to that year (the O group), his view being that they had come into the world the previous winter and spring. Our investigations, however, repeatedly gave us larvæ of the same size, but taken in winter and spring. Thus, for instance, we had three specimens taken early in December not far from the Azores (station 397), measuring 43, 48, and 56 mm.; other samples taken in March and April contained specimens measuring 47, 49, 50, 57, and 59 mm. in length. It, therefore, seemed doubtful

[9] "Danish Researches in the Atlantic and Mediterranean on the Life History of the Fresh-Water Eel (*Anguilla vulgaris*)," ("Internat. Revue der gesammten Hydrobiologie und Hydrographie," Leipzig, 1912).

whether Hjort's interpretation of his specimens taken in summer as being first year larvæ could be correct, since if this were the case one would have expected to find much smaller specimens in winter. There was, however, the possibility that both Hjort's summer specimens and our winter specimens were in their first year, but if so, it had to be presumed that a regular production of ova and larvæ took place all the year round, so that not the season, but the locality, i. e., the distance from the site of production, would be responsible for the size of the larvæ. There were, however, several facts which spoke against the theory of such uninterrupted production, as, for instance, the periodicity in the occurrence and metamorphosis of the larvæ which I had discovered on board the *Thor* in 1905–1906.

The net result, then, of our investigations by the close of 1912 was that a great deal more research work would be needed, since the new data obtained had practically raised new difficulties in the way of an interpretation—as, indeed, often happens when an investigation has passed beyond the earliest stages, when the paucity of facts gives freer play to the imagination.

The year 1913 was marked by important progress. Not only did our fishing cargo vessels send us in richer material, but we succeeded in getting the little schooner *Margrethe*, belonging to the Vendsyssel Packing Co., of Copenhagen, equipped and sent out on a cruising expedition over the Atlantic, with a supply of nets, etc., for pelagic work. The investigations were carried out during the months of August–December along the following three lines: (1) From the Faroes to southwest of the Azores (about 28° N., 40° W.); (2) thence to the Newfoundland Banks; and (3) from there to the West Indies. The yield was 714 larvæ of the European eel, besides a small number (24) of the American. We had now at last obtained a large amount of material from the open Atlantic Ocean, and the study of this yielded important results. It was very significant, in the first place, that the larvæ increased in numbers from east to west, the greatest quantities being taken west of long. 50° W. In this area the *Margrethe* succeeded in taking no less than 154 specimens at one station (station 1040) with a net 2 m. in diameter at opening, and one of the sailing vessels fishing for us, the schooner *Agent Petersen*, took 24 specimens in one haul with a small net only 1 m. in diameter (station 765). By way of comparison, it may be mentioned that our greatest number of larvæ per haul in the eastern Atlantic, with the far more intensively working *Thor*, was 70.

No less interesting was the size of the larvæ at the different stations. The following representative stations will serve to illustrate this:

Sizes of eel larvæ (Anguilla vulgaris) at stations from east to west, lat. 35° N.; Margrethe, September, 1913

Longitude	Station No. and date	Length in mm.
29° W.	1013, 24/8	65, 63, 59.
45° W.	1020, 11/9	55, 53, 50.
56° W.	1030, 1/10	40, 36, 35.

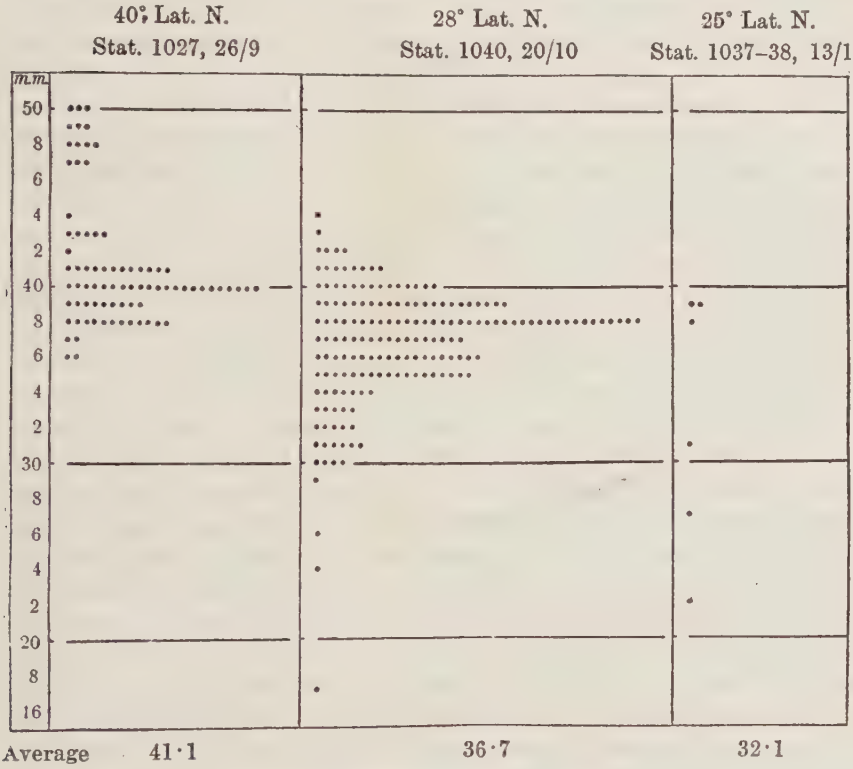


Fig. 4.—European eel (*Anguilla vulgaris*)

Sizes of larvæ at stations from North to South, western Atlantic between 50° and 60° long. W.; *Margrethe*, October, 1913.

It will be seen from the above measurements that the sizes of the larvæ decrease from east to west and from north to south. A good general idea may also be gained by marking off the *Margrethe's* hauls on a chart of the North Atlantic, and drawing a line from Newfoundland in a southeasterly direction, toward Cape Verde. It will then be seen that, west of this line, no larvæ over 5 cm. in length were taken, whereas most of those taken east of this line were 5 cm. or more, and none less than 4 cm.

It had now been shown, by systematic investigation across the Atlantic Ocean, that the larvæ of the European eel increase in num-

ber, but decrease in size from east to west. This placed it beyond doubt that the stock of eels in Europe must have its origin in an area situated far to the west in the Atlantic Ocean.

The question now was, what further conclusions could be drawn from the wealth of material obtained from the *Margrethe's* 73 stations, comprising as it did, apart from larvæ of the fresh-water eel, close on 10,000 larvæ of other eel fishes.

In October and November, and the early part of December, 1913, the *Margrethe* was working in the western part of the Atlantic, between Newfoundland and the West Indies, in the course of which cruise the northern and southern limits of distribution of the larvæ of the European eel were determined. They were found to occur from about 40° N. latitude (a bare 200 miles south of the Newfoundland Banks), to about 24° N. latitude. To the westward specimens were found as far as our investigations reached, viz, to Bermuda and the sea to the south of there, i.e., to about 65° W. longitude, and even here they were present in great numbers. This was an astonishing fact, for one would hardly have expected to find the larvæ of our European eel as a numerous population in Atlantic waters so far west as 65°—New York lies about 74°! Larvæ of the American eel were also taken in our nets, but in remarkably small numbers, amounting to only some few (3–4) per cent of the total number of *Anguilla* larvæ.[1] Here, again, a new problem arose; for how could it be that Bermuda was, as it were, surrounded by a belt of larvæ of the European eel, when all the specimens of fresh-water eels I had previously examined from these islands had proved to belong to the American *Anguilla rostrata?* It was not until several years after that we were to learn the explanation of the mystery; the time was not yet ripe for its solution.

We now come to the size of the eel larvæ taken on the cruise of the *Margrethe.* The smallest eel larva hitherto known was, it will be remembered, one measuring 34 mm. in length, but this was only a single isolated find, and did not count for much. On the other hand, it was to be expected that the great mass of material from the *Margrethe*, systematically collected as it was, would furnish valuable data as to the size of eel larvæ in autumn. We were, of course, still without any answer to the important question as to whether larvæ were produced uninterruptedly throughout the year, or if a particular season of the year could be defined as the breeding season of the eel. Not until these points were settled should we have anything to go upon in judging the age of the older larvæ from the central and eastern Atlantic.

[1] The larva of the American eel was described in 1902 by Eigenmann and Kennedy from two specimens, 47 and 49 mm. in length, taken by the U. S. S. *Albatross* in 1883 at about 38°–39° N. lat., 72°–73° W. long. (Bull. U. S. Fish Commission, XXI, 1902). I do not know of other records from the literature of the larvæ of the American eel.

The graph, station 1040, Figure 4, gives a good idea of the size of the larvæ in autumn in the western Atlantic. In the first place, it will be seen that the smallest specimen was 17 mm. long only—a marked lowering of the previous minimum record of 34 mm.—but, despite the intensive fishery, only a single specimen of this small size was taken throughout the whole cruise, and only a very few slightly larger, 2–3 cm., amounting to 1–2 per cent of the total number. Furthermore, the graph shows that an overwhelming majority of the larvæ were of sizes varying between 3½ and 4½ cm. in length. (As mentioned above, no specimen over 5 cm. was taken by the *Margrethe* in the western area, west of the line referred to on page 291.)

These facts, in my opinion, warranted the following conclusions: The spawning of the eel can not go on regularly throughout the whole year; there must, in autumn at any rate, be a cessation or decrease in the production, otherwise we must have found tiny larvæ in greater numbers at this season. Even though the time when the eels did spawn could not be determined with certainty, the size of the larvæ nevertheless rendered it likely that they had come into the world during the first half of the year 1913. We were dealing, that is to say, with larvæ in their first year (the O group), and these were as we have seen about 3½ cm. long in the autumn.

Since tiny larvæ were, practically speaking, unrepresented in the *Margrethe's* collections, it was impossible at that season to determine with any certainty the locality of the breeding grounds, since if the larvæ were even a few months old—which must seem probable—we could not overlook the possibility of their having been carried by ocean currents far from their place or origin. A calculation of the average length at the different stations, however, was not without interest in this connection, the differences, although not great, being nevertheless beyond doubt. The lowest average lengths, for instance, were found at stations situated about latitude 26° N., longitude 55° W.; from here the larvæ increased in size both toward the north and toward the northwest (in the direction of Bermuda). To the south, as mentioned, the larvæ were entirely lacking.

This was, generally speaking, the result of the work of the *Margrethe* on her cruise to the West Indies. It had been intended to spend the winter in fisheries investigations at St. Thomas, and then, following up the work of the outward voyage of the *Margrethe*, to continue the eel investigations during the voyage home in spring. Fate, however, ordered otherwise; the *Margrethe* ran aground on one of the West Indian islands and was wrecked.

The collections, fortunately, were saved, but here we were at St. Thomas with no ship. The only thing to be done for the moment was

to endeavor to press forward, the work being done from the trading vessels. We had now, of course, some definite facts to go upon. We knew that the tiny larvæ were to be sought during the first half of the year, and the record specimen of only 17 mm. length, already frequently referred to, would also be a good guide. I was now able to issue instructions far more precise in character than hitherto, both as regards time and place, and also the depth, to be chosen for fishing. Through the very generous cooperation of the East Asiatic Co., of Copenhagen, a considerable number of hauls were taken in the spring and summer of 1914 by steamers of this line on the West Indies route, and these did not fail to produce their result. As early as June, the steamship *Samui* and steamship *Bintang* brought us plankton samples, taken in May and June about latitude 26° N., longitude 55° W., all of which were found to contain larvæ of the European eel, for the most part tiny stages. At one of the stations, for instance (station 789, 8/5, 1914) seven specimens of the following lengths were taken: 9, 9, 11, 16, 16, 16, 21 mm., i. e., an average of 14 mm., and another (station 793, 11/6, 1914) yielded eleven specimens averaging 18.1 mm. in length.

On returning from the West Indies we set about endeavoring to get another schooner to work in place of the *Margrethe*, but then came the great war, and all plans for further researches at sea had to be laid aside. The work of the trading vessels, however, was maintained during the first years of the war and continued to yield valuable information. In 1915, for instance, we obtained confirmation of the fact that tiny larvæ occur in summer, and a sample taken at the end of September, 1915, contained eight specimens of about 3½ cm. long, i. e., of the same size as those taken by the *Margrethe* in the autumn of 1913. As the war increased in extent, however, our collecting work died out, and several of the vessels which had been assisting us were sunk by submarines. During the next five years, therefore, from 1915 to 1920, the investigations at sea were altogether at a standstill; I was able, however, on the basis of material from the western Atlantic, to work out a description of the development of the larvæ of the two *Anguilla* species and a series of other Atlantic murænoids (1916).[10] The larvæ of the European eel were now known in all stages of development, from that of 9 mm. up to full-grown larvæ averaging 7½ cm. in length, and in their metamorphosic stages. I was also able to describe the development and metamorphosis of the larvæ of the American eel, which proved to be considerably smaller—1 cm. at least—than that of the European, in a fully grown state.

[10] "On the Early Larval Stages of the Fresh-Water Eels (*Anguilla*) and some other North Atlantic Murænoids" ("Meddelelser fra Kommissionen for Havundersögelser, Serie Fiskeri," Vol. V, No. 4, Copenhagen, 1916).

The few metamorphosic stages of the American eel I had at my disposal I had found in a collection of murænoid larvæ from a cruise of the United States ship *Bache* sent me by the United States Commissioner of Fisheries, Dr. Hugh M. Smith, of Washington. The work of the *Bache* was carried out in January, February, and March, 1914, in connection with the program of the International Council for the Study of the Sea, in the Gulf Stream area and along two sections between Bermuda and the United States coast. The collection consisted of several hundred murænoid larvæ, among which I found 37 specimens belonging to the genus *Anguilla*, taken near Bermuda or in the waters between there and the United States. Closer examination showed that only 6 of these 37 belonged to the American species, the remainder being larvæ of *Anguilla vulgaris*, 4–5 cm. in length. Thus the collections from the *Bache* furnished additional evidence of the mysterious fact that, as we had shown in 1913, the larvæ of the European eel may, even in the American waters of the Atlantic, predominate greatly over those of the species of eel which has its habitat in America. A remarkable feature of the case was that at more than one of the *Bache's* stations, as also of the *Margrethe's*, larvæ of both species were brought up in the same net at the same time. I shall later, in dealing with the investigations undertaken by the schooner *Dana*, return to this point, which I found altogether incomprehensible at the time.

The collections of material from trading vessels had, in the five years they covered, been of great assistance to us, first and foremost by showing in what parts of the Atlantic eel larvæ were to be found and where they were lacking. We were, however, indebted to them for more than this. During the last two years during which such collections were made—1914 and 1915—the West Indies steamers had regularly brought us in larvæ so small in size that we were able with perfect certainty to conclude therefrom that the steamship route from the English Channel to St. Thomas must pass through the breeding grounds of the eel. This was indeed a point of the highest importance in the task we had before us: to chart the spawning area of the eel. Ships bound to follow a certain particular route, however, could not, of course, assist us in ascertaining the boundaries of such an area. Altogether, matters were now so far advanced that we could hardly expect to gain any great further advantage from occasional hauls by trading vessels. For the work now to be done we needed a vessel specially equipped, which could be employed on that work all the time, and follow any course laid down, as might seem desirable from the results of expert examination of the material on board from one station to another.

Our endeavors were accordingly directed toward this end as soon as the war ceased, and it was possible once more to think of work

at sea. The plans met with great difficulties, but, on the other hand, were strongly supported in various private quarters, both with financial help and in other ways. Particularly effective was the assistance here rendered by the East Asiatic Co., of Copenhagen, which I have already had occasion to mention in a like connection, and whose director, His Excellency H. N. Andersen, placed at our disposal a vessel, fully ready for sea and actually at work, the four-masted motor schooner *Dana*, of 550 tons, for the purpose of these investigations.

With the schooner *Dana* and with the steamship *Dana* we have, during the years 1920–1922 made hauls at a great number of stations. Most of the stations were situated in the western Atlantic. A great quantity of material was obtained; this has not, however, yet been dealt with in detail, especially the yield of 1921–1922. The murænoid eggs have not been identified as yet, and I have therefore been unable to take them into consideration.[11] For the purpose of mapping out the breeding grounds of the eel I have employed—as previously when dealing with the Gadoids—the earliest larval stages, less than 10 mm. in length. These are so tiny that there can be no question of their having moved any considerable distance from the spot where the eggs were spawned.

These tiny larvæ were found at a considerable number of stations. On marking these off upon a chart (fig. 5), it will be seen that the breeding grounds of the European eel form a continuous area situated in the western Atlantic between about 22° and 30° N. latitude and about 48° and 65° W. longitude. The central portion will be found to lie about latitude 26° N., or approximately equidistant from the Leeward Isles in the West Indies and from Bermuda.

It is on the 1920 investigations in particular that the chart is based. As to how far the area may vary in extent from one year to another I am unable to say. This much, however, is certain, that tiny larvæ, less than 10 mm. in length, have now been found within this area in no fewer than five different years, viz, 1914, 1915, 1920, 1921, and 1922.

The position of the area will be seen from the charts, Figures 5 and 6, where it is indicated by the heavily drawn curves, which I have termed the 10-mm. line, as marking the limits of occurrence of larvæ less than 10 mm. in length. Similar lines have been drawn for the 15, 25, and 45 mm. limits, taking all our finds of eel larvæ 1904–1921 into consideration. I shall revert later on to these curves

[11] Since it has been questioned whether the ripe eggs of the eel contain oil globules, I may mention in this connection that the remnants of the yolk sac found in the earliest larval stages prove to contain a large, quite distinct oil globule (see also fig. 13 showing a prelarva). This observation confirms the conclusion arrived at by T. Wemyss Fulton in 1897 from the study of the ovarian eggs of the eel.

and the conclusions which they warrant in regard to the trans-oceanic migrations of the larvæ. First of all, I propose to deal with their occurrence on the breeding-grounds in the western Atlantic.

In the latter half of April, the average length is about 12 mm.; in May, June, and July, it is increased, but in each of these months specimens less than 10 mm. are found. From this we may conclude that the spawning season of the eel commences in late winter or early spring and lasts to well on in summer. In autumn and early

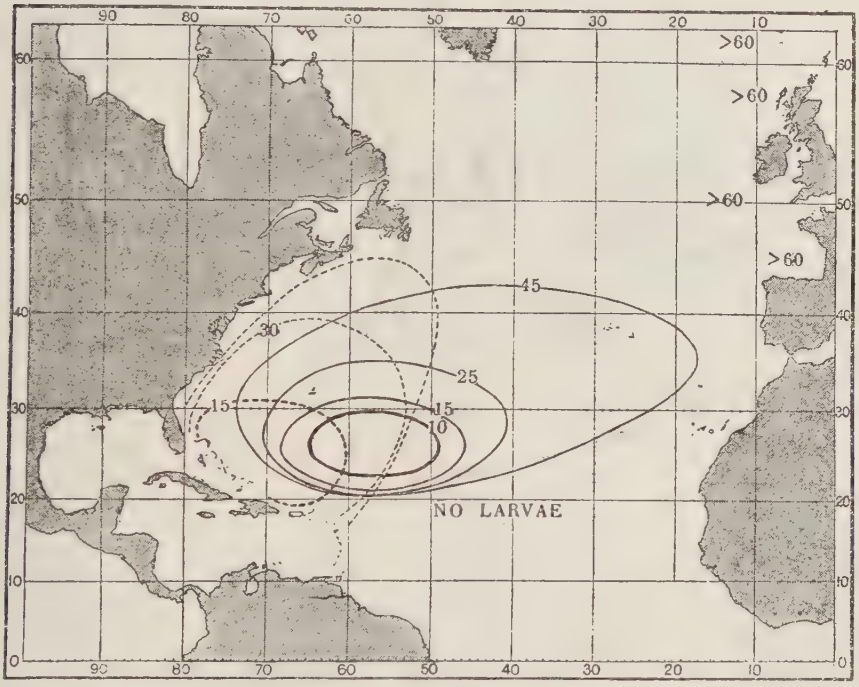


FIG. 5.—European Eel (*Anguilla vulgaris*) and American Eel (*Anguilla rostrata*)

Breeding areas and distribution of larvæ shown by curves (dotted for the American, continuous for the European species). The heavily-drawn innermost curves embrace the breeding areas of the two species. The curves show limits of occurrence; i. e., specimens less than 25 mm. in length have only been found inside the 25 mm. curve, etc.

winter tiny larvæ were not found, as mentioned when dealing with the *Margrethe's* investigations in 1913.

The *Dana* stations from June, 1920, within the breeding area yielded large hauls, which gave us an extremely lucid picture of the larvæ of that year (the O group) which in June averaged about 25 mm. in length. By way of example we may take a haul of two hours' duration at about 50 m. depth, station 871 (lat. 27° 15′ N., long. 61° 35′ W.) on June 27, 1920. The contents of the net when drawn on board presented a remarkable sight: Of the pelagic forms it contained the great majority were larvæ of our European eel.

A count showed close upon 800 specimens (reproduced here in the photograph, Plate 4, measurements in the graph, fig. 8). This one haul alone gave us a greater number of specimens of eel larvæ than had hitherto been obtained in the whole course of any

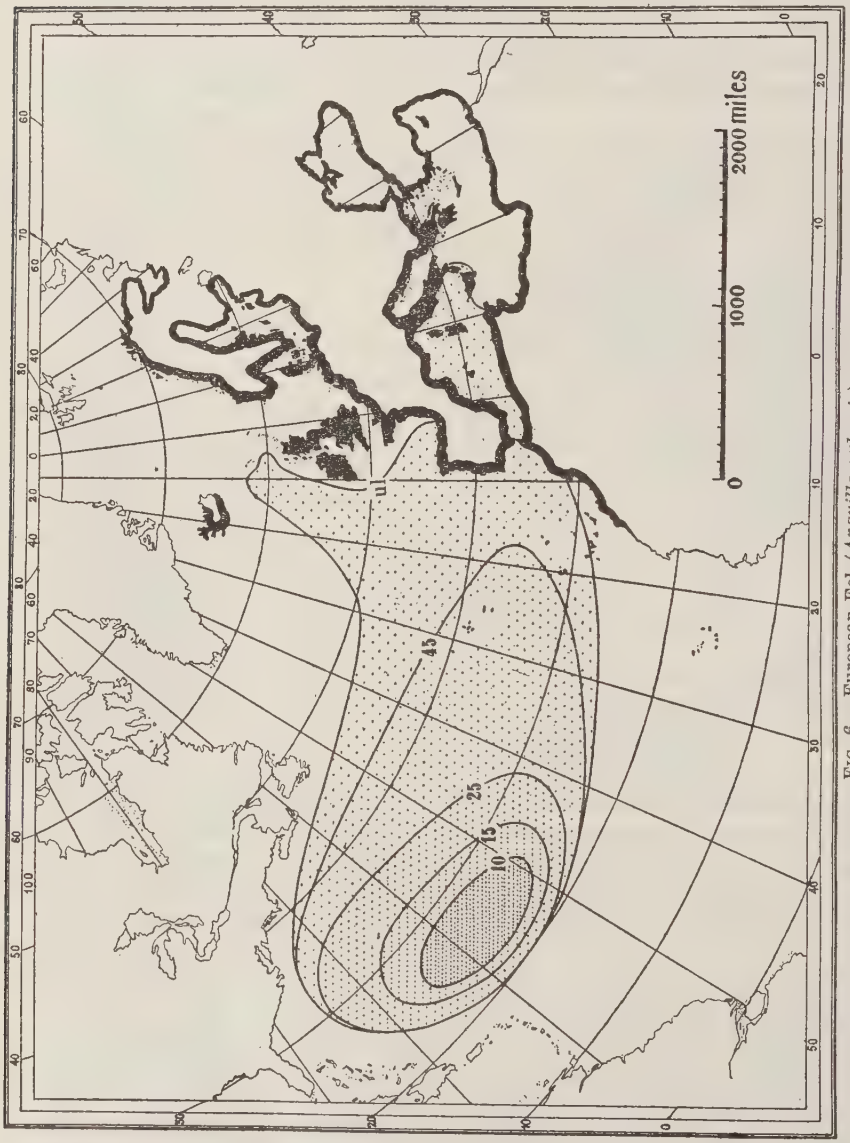


FIG. 6.—European Eel (*Anguilla vulgaris*)
Distribution of larvæ (dotted area) *and of adults* (black strip along the coasts where the species occurs). The curves show limits of occurrence; i. e. larvæ less than 10 mm. have only been found inside the 10 mm. curve, etc. The outermost curve denotes the limit of occurrence of unmetamorphosed larvæ (ul). (From Johs. Schmidt, *Nature*, London, January 13, 1923, slightly altered.)

expedition. It affords us, in conjunction with many other hauls from the *Dana* stations, a clear idea of the enormous quantities in which the young larvæ of the European eel are present here in the western Atlantic.

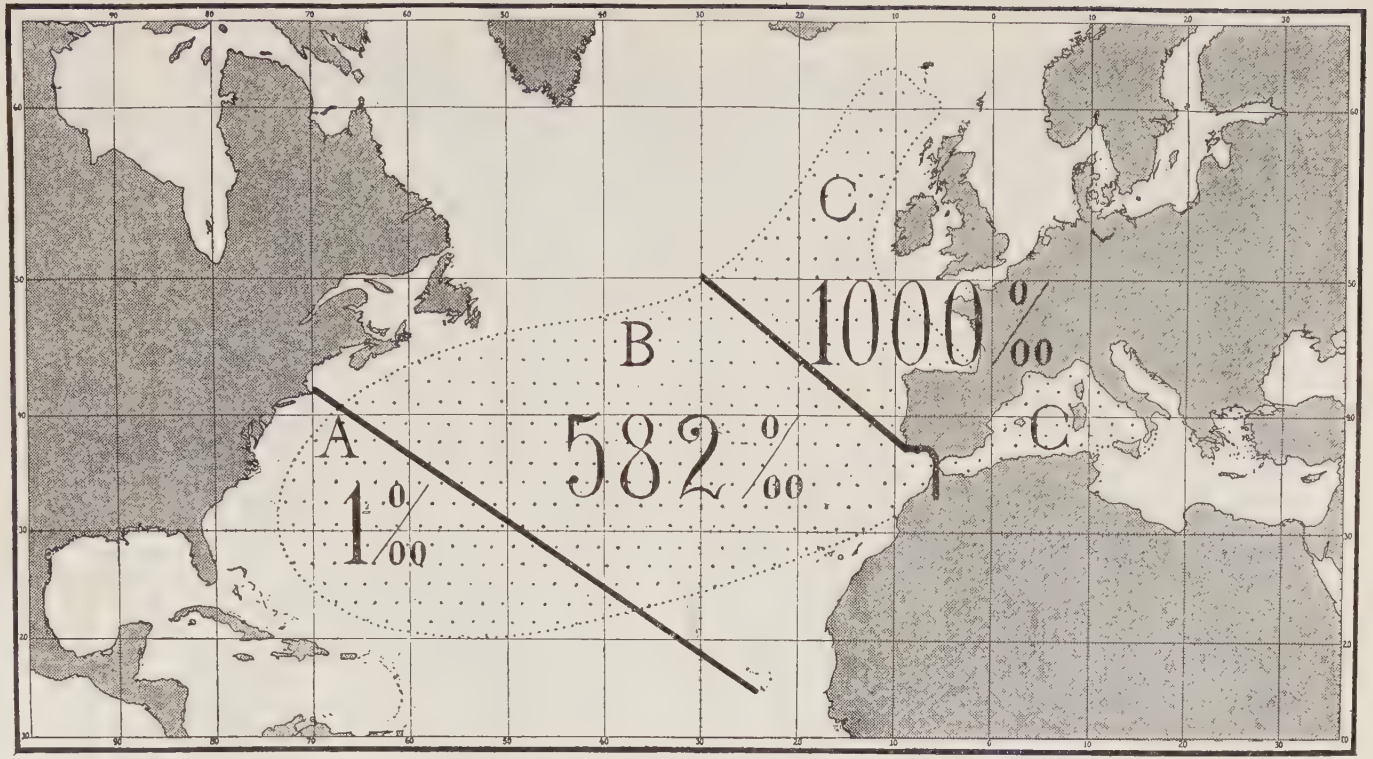


FIG. 7.—Distribution of the larvæ of the European Eel (*Anguilla vulgaris*) according to all existing records (1923), showing the number of specimens more than 50 mm. long per mile.

The region where larvæ were found is shaded.
Area A: 7018 specimens.
Area B: 794 specimens.
Area C: 4871 specimens. (Atlantic, 869 + Mediterranean, 4002.)
The chart shows that the larvæ come from A and, as they grow, move via B to C, shaping their course roughly toward the northeast.
(From Johs. Schmidt, *Nature*, London, January 5, 1924).

As mentioned, the average length in June was about 25 mm., and the great majority of larvæ of this size were found to occur near the surface—from a depth of about 50 m. to the surface itself. The younger larvæ (7–15 mm. long) were taken somewhat deeper, at depths ranging from about 300 to about 75 m.; but it must be borne in mind that the depth of the ocean here is over 6,000 m. We may, therefore, assert that the larvæ of the eel, even at these early stages of development, are true pelagic organisms, pertaining to the upper water layers, as the 1905 investigations had shown was the case with the full-grown larvæ.

A closer investigation of the sizes of the larvæ from the *Dana* stations in the western Atlantic is of interest. The figures provide

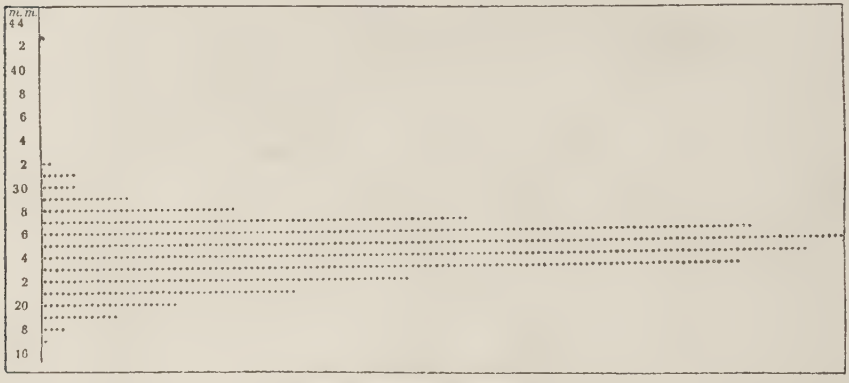


FIG. 8.—European Eel (*Anguilla vulgaris*)

Sizes of larvæ caught in a single haul of two hours' duration at "Dana" station 871 (lat. 27° 15′ N., long. 61° 35′ W.) in the western Atlantic, June 27, 1920; depth about 50 m. (same haul as that represented in fig. 10). The largest specimen shown belongs to the I group, the remainder to the O group.

a far sounder basis for determining the age of the larvæ that we had before. Figure 10 shows the sizes of the youngest year class (the O group) in April, 1921, and Figure 8 the O group in June, 1920. The measurements from June are from specimens taken in a single haul. If we include the entire material from the *Dana* stations in June, 1920, we find that the O group varies from 7 to 37 mm., with an average length of about 25 mm. We have a very large quantity of material from the month of June, between four and five thousand specimens, so that the average length of the group for this month is determined with a high degree of accuracy.

Now it has been noticed for several years, that in spring a few eel larvæ, between 40 and 50 mm. long, appear in or near the spawning area in the western Atlantic. In June, 1920, also, some of these larvæ—78 in all—were taken by the *Dana*, more especially in the northern part of the area.

LARVAE CAUGHT IN A SINGLE HAUL OF TWO HOURS' DURATION AT "DANA" STATION 871 (LAT. 27° 15′ N., LONG. 61°, 35′ W.) IN THE WESTERN ATLANTIC (SAME HAUL AS THAT REPRESENTED IN THE GRAPH, FIG. 8, BELOW, A 11-GROUP SPECIMEN, LENGTH 74 MM., FROM THE EASTERN ATLANTIC, IS SHOWN FOR COMPARISON

The measurements will be seen from Figure 8, showing one, and Figure 10, showing three of these larvæ among the O group. The graph, Figure 9, also indicates the lengths of the largest specimens of the O groups, which, as mentioned, varied at this season from 7 to 37 mm. It will be noticed that the millimeter scale shows a distinct interval between the O group and the group of individuals between 40 and 50 mm. In June it lies about 38–39 mm., being then but slight; in the spring, on the other hand, when the O group is much smaller, the interval between the two groups is, of course, far more pronounced (see fig. 10). There can thus be no doubt that the group of 40–50 mm. length represents the remainder of the previous year-class (the I group); individuals which have not yet succeeded in moving any considerable distance from the breeding-grounds. In Figure 9 then, we have the uppermost portion of the O group and the lowest portion of the I group taken at the same time and place; the figure thus serves very satisfactorily to show the limit between the two year-classes in the month of June. The *Dana* stations in July, 1920, also, in the outer parts of the breeding area, show a distinct interval between the O and I groups; here, however, it is found a little higher up the scale, on account of the growth which has taken place. Even in September there is a trace of what is probably the same at the *Margrethe* station 1027, south of the Newfoundland Banks, the interval in this month lying at about 45–47 mm. length (fig. 4, p. 291).

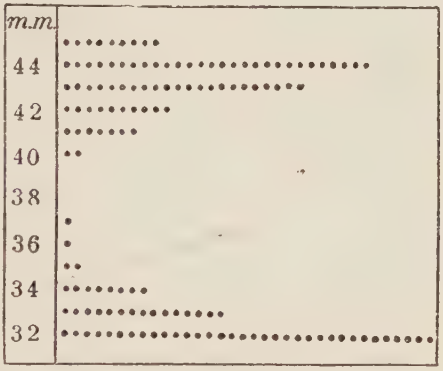


FIG. 9.—European Eel (*Anguilla vulgaris*) Western Atlantic (west of 50° long. W.), "Dana," June, 1920. Showing limit between O group and I group

We are now enlightened as to the sizes of the larvæ in the western Atlantic at the different seasons. The larvæ found here, i. e., west of long. 50° W., are almost without exception under 50 mm. in length. They belong to the two youngest year-classes, the O group being by far predominant in point of numbers. Its average length in April is about 12 mm., in June about 25 mm., and in October 30–40 mm. During the second half of the year the bulk of the O group move away from the breeding area, but a number of individuals—the numbers varying from year to year—do not manage to get away, and we find them, then, in the spring and early summer as the I group, especially in the northern part of the area, about latitude 30° N. In June, 1920, the average length of these was 43–44 mm.; in

other years they may be a little larger. They represent the last or youngest portion of the I group, the great majority of which have already moved away from the area.

From our investigations with the *Thor* in 1905–1906, it will be remembered that the full-grown larvæ occur in early summer outside the coastal banks to the west of Europe. They vary in length from 60 to 88 mm.; in June, 1905, the average was about 75 mm. (fig. 2). In the same month the great bulk of the O group, averag-

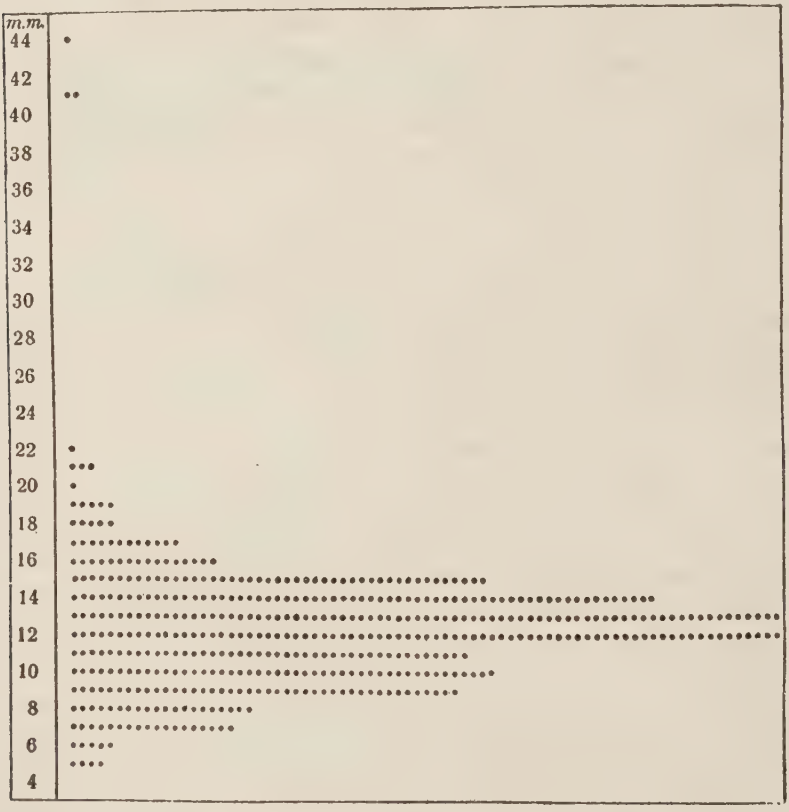


FIG. 10.—European Eel (*Anguilla vulgaris*)

Western Atlantic (west of 50° long. W.), "Dana" Stations 935–948, April, 1921; O group and three specimens of I group.

ing 25 mm. in length, are still on or near the breeding grounds. During the journey, then, from here to the shores of Europe, these larvæ grow on an average 50 mm. Plotting the lengths for the different months in a graph, we find that the larvæ take on an average two years to grow so much (fig. 11). The full-grown larvæ in Figure 2 from June, 1905, thus represent the II group, and are, on an average, two years older than the 25 mm. larvæ from the western Atlantic shown in Figure 8 and on Plate 4.

The intermediate year-class—the I group—is, judging by the available data, to be found during early summer in the central Atlantic, between about 50° and 20° W. longitude, its average length being, then, 50–55 mm. Our trading vessels caught them in May in quite considerable numbers, and there can hardly be any doubt that it was this I group to which the score of specimens taken by the *M. Sars* expedition in June, 1910, to the south and west of the Azores, really belonged (see p. 287). Later in summer I group larvæ have been taken both by the *Margrethe* and the *Dana* in the neighborhood of the Azores, and in February by the *Thor* near Gibraltar, the average length here being about 66–67 mm.

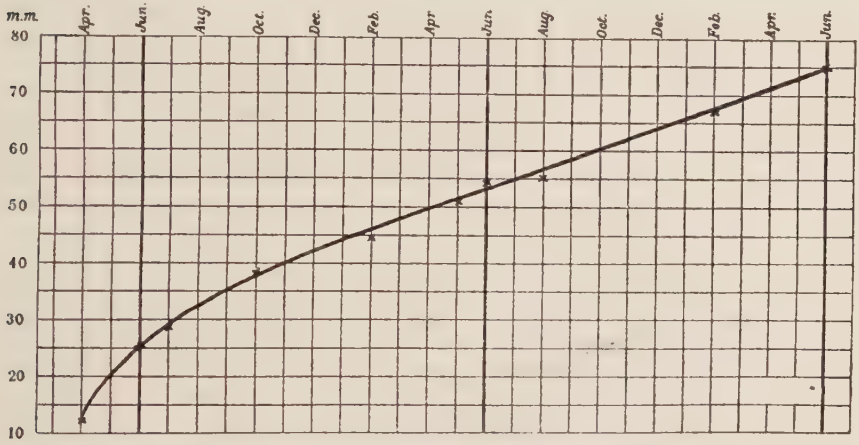


FIG. 11.—European Eel (*Anguilla vulgaris*)
Curve showing rate of growth of larvæ.

We can now draw up the following table, showing:

Larvæ of the European eel in early summer (June)

Year class	Central position	Length in mm.	Average length in mm.
O Group	Western Atlantic	7–37	25
I Group	Central Atlantic	40-about 70	52
II Group	Off Europe	60–88	75
(III Group	Fresh and brackish waters of Europe	Elvers just metamorphosed.)	

The eels, then, spawn in spring, their larvæ take on an average about two years to attain full larval size, and nearly three years elapse before the metamorphosis is completed. The elvers, which make their appearance on our shores in spring, will accordingly be, on an average, about three years old.

The illustration, Plate 6, Figure 2, shows the same as the table above.

Reverting now to the distribution of the various larval stages in the Atlantic, let us glance once more at the charts (figs. 5–7). I may supplement the indications there given by noting here our northernmost, southernmost, westernmost, and easternmost finds of larvæ of the European eel:

Larvæ of the European eel (Anguilla vulgaris)

Northernmost find: Lat. 61° 21′ N., long. 10° 59′ W. (*Thor*).
Southernmost find: Lat. 20° 14′ N., long. 57° 03′ W. (*SS. Tranquebar*).
Westernmost find: Long. 73° 43′ W., lat. 35° 42′ N. (*Dana II*).
Easternmost find: Long. 15° 35′ E., lat. 38° 07′ N. (*Thor*).

The result may be briefly expressed as follows: The larvæ were found all across the Atlantic Ocean, coastal waters excepted, but only north of the twentieth degree of latitude north. In the easternmost part of the Atlantic they extend northward beyond the sixtieth degree of latitude. These facts will give an idea of the enormous extent of the area in which larvæ of our European eel occur.

The starting point for the transoceanic migration of the larvæ is the area encircled by the heavily drawn line in the charts Figures 5 and 6. If the annual production of eel larvae only occupied a very brief period, say one month, and provided that all individuals came from the same spot and made equal progress, alike in their growth and in their movement eastward, then it would be an easy matter to indicate the position of each particular stage of development in the ocean by curves representing the average lengths of the specimens. As it is, neither of these conditions is fulfilled, and it is difficult, therefore, to draw up a clear and simple chart of the material. After various experiments in this direction I have adopted the method of noting on a large chart the minimum length of the specimens found at each station, these values being then used in constructing the curves shown in Figures 5 and 6. These curves are to be understood as limits of occurrence, i. e., specimens less than 25 mm. have only been found within the area embraced by the 25-mm. line, and so on.

The chart gives the main sum of the conclusions to be drawn from the material collected in the course of years. The position of the curves clearly shows that the principal resultant of the movement of the eel larvæ from the breeding grounds is directed toward northeast; that is to say, toward Europe. It will be noticed that there is also a certain movement toward the north and northwest. From the data available it is not easy to determine in what direction the main body of the larvæ commence to move. From investigations with the *Dana*, in 1920, it might seem as if the majority started with a northward move and did not turn eastward until they had reached several degrees farther north. On the other hand, our investigations of 1913 with the *Margrethe* seem to show that great numbers of larvæ can

take a more direct northeasterly course from the breeding grounds. The probability is that differences will be found to occur in this respect as between one year and another and also as between different parts of the breeding grounds.

Anyhow, the result of the movement is that no full-grown larvæ of the European eel are met with in the western Atlantic. As already mentioned, it was altogether exceptional to find specimens over 50 mm. in length west of 50° W., and we have never taken a single one over 60 mm. in this portion of the ocean (cf. fig. 7).

During the initial period of our investigations in the eastern Atlantic and the Mediterranean we had no occasion to concern ourselves with the American eel (*Anguilla rostrata*) and its larvæ. Later on, however, circumstances changed, after it was found that our researches in connection with the European species would have to be extended farther west. The collections here made by the trading vessels, and by the *Margrethe* in 1913, brought us already certain specimens which, though outwardly indistinguishable from *Leptocephalus brevirostris*, proved, on being tested for number of muscle segments (myomeres), to belong to the American eel. These larvæ were taken in the same area as those of the European species, even, indeed, at one or two of the *Margrethe's* stations, in the same haul. It was with mingled feelings that we noted this fact, since it involved a further complication of the eel question, which at this point seemed more intricate than ever. Technically, also, it increased the difficulty of our investigations, since the only means whereby the larvæ of the two species can be distinguished one from the other is by counting, under the microscope, the 104–120 myomeres in each individual specimen—a very lengthy and laborious business, especially on board a small vessel at sea.

After the cruise of the *Dana*, in 1920, I look upon the matter in quite a different way. True, the technical difficulties have not diminished—I have in mind the counting of myomeres in the thousands of specimens obtained on the cruise—but the comparison of the life history of the two species which our investigations have enabled us to make is, to my thinking, one of the most interesting chapters in the history of the eel. Indeed, it is hardly too much to say that the life history of the European eel can only be properly understood at all by comparison with that of the American. This will be seen from what now follows.

At the *Dana* station 827, southeast of Bermuda (30° 47′ N., 62° 27′ W.), we made a haul on June 13, 1920, at about 25 meters depth, bringing up 150 *Anguilla* larvæ. These were measured, as usual, as soon as possible after preservation, giving the result shown in Figure 12, A. Believing that we had here solely to deal with *Leptocephalus brevirostris*, we naturally regarded the haul as practically

representative of the youngest year class (the O group), and a few specimens of greater length than the majority would simply be regarded as born somewhat earlier than the rest. On counting the myomeres of the whole batch, however, which was done in the course of the next few days, we arrived at an altogether different result, and one which is of interest in more than one respect. It was now found that out of the 150 specimens, 94 belonged to the American eel and 56 to the European eel. Figure 12, B and C, gives the respective values separately shown. They are now seen to have an entirely different meaning. The specimens of both species are of the

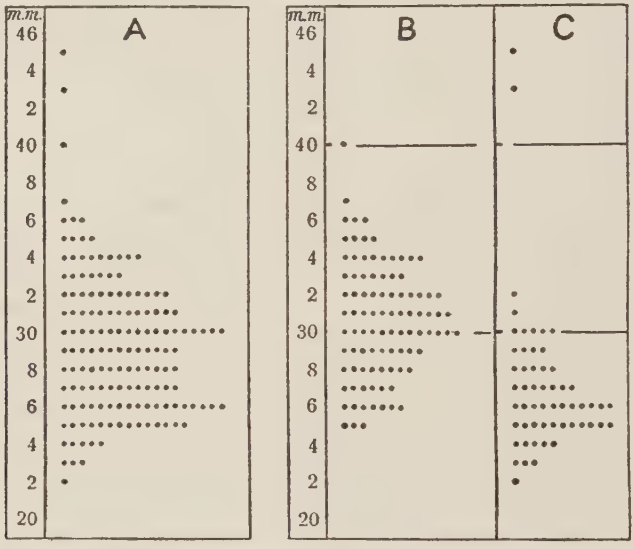


FIG. 12.—European Eel (*Anguilla vulgaris*) and American Eel (*Anguilla rostrata*)

Sizes of larvæ from one haul at "Dana" station 837, 30° 47′ N., 62° 27′ W., depth about 25 m., June 13, 1920.

A.—Sizes of total catch. B and C.—Same individuals as in A after their identification by means of counting the myomeres. B.—*Anguilla rostrata*, all of the O group. C.—*Anguilla vulgaris*, two of the I group, the remainder of the O group.

current year class (the O group), but those of the American eel are, on an average, larger than those of the European. From this we may conclude that the former species must spawn earlier or grow more rapidly than the latter. Furthermore, we notice that the two specimens of the European eel of 43 and 45 mm. are so much larger than the bulk of the specimens belonging to this species, that they must be supposed to be leftovers from the previous year (the I group). These conclusions were frequently confirmed as the cruise went on. Plate 5 shows, in the form of an illustration, the contents of a similar haul. Both serve well to show how delicate an analysis is needed in the classification of material before it can be used as a basis

for biological conclusions. The following figures show the numerical proportion between the larvæ of the two species in our collections:

	Anguilla rostrata	*Anguilla vulgaris*
Captain Andrea (about 1865)	1	2
Trading vessels, 1911–1915	3	120
Margrethe, 1913	24	714
U. S. S. Bache, 1914	6	31
Dana, 1920–21	1868	6446
Dana II, 1921–22	>400	>4500

In all the collections the European eel predominates, even in the western Atlantic. This is possibly the case also in reality. The collections can hardly be taken as properly representative; in all probability that of the *Dana* (1920–21) is nearest the true state of things. In any case it is interesting to note that the *Dana's* hauls in the western parts of the ocean (west of 50° W.) yielded several times as many larvæ of the European as of the American eel. As far as can be determined from the incomplete statistics available, the annual yield of the eel fisheries in Europe is several times that in America (in America a little more than 2,000 tons, in Europe more than 10,000 tons).

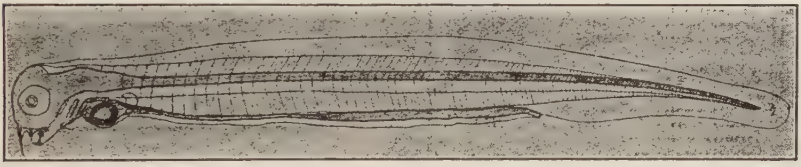


FIG. 13.—Prelarva of European Eel (*Anguilla vulgaris*). May 5, 1922, 700 meters of wire out. Length about 6 mm. "Dana II," Stat. 1331, 26° 37′ lat. N., 55° 50′ long. W. Note the developing teeth, the pigmentless eye, the large oil-globule and the pigment on the caudal portion of the embryonic fin. (Drawing by A. V. Tåning, M. Sc.)

As in the case of the European eel, I note here the extreme limits for our finds of the larvæ of the American species.

Larvæ of the American eel (Anguilla rostrata)

Northernmost find: Lat. 42° 19′ N., long. 50° 22′ W. (*Margrethe*).
Southernmost find: Lat. 17° 55′ N., long. 64° 48′ W. (*Dana*).
Westernmost find: Long. 82° 59′ W., lat. 20° 08′ N. (*Dana II*).
Easternmost find: Long. 50° 22′ W., lat. 42° 19′ N. (*Margrethe*).

I would also refer to Figures 5 and 15, where the occurrence of the larvæ of the American eel is indicated by curves. The result may be briefly stated as follows: We found the larvæ throughout the greater part of the western Atlantic between the West Indies and the Newfoundland Banks, where they occur together with the larvæ of the European eel. East of 50° longitude W. we have not met with larvæ

of the American eel, which have thus a far more limited area of occurrence than those of the European species just as we have found to be the case with the larvæ of the American conger.

Most of the *Dana* stations in June-July, 1920, west of 50° W., gave larvæ of both species, but *Anguilla vulgaris* was, as a rule, the more numerous. The larvæ of the two species were by no means evenly distributed throughout the area; west of about 62° W. longitude, and south of about 24° N. latitude, *Anguilla rostrata* predominated over *Anguilla vulgaris*, and in this part of the area we took

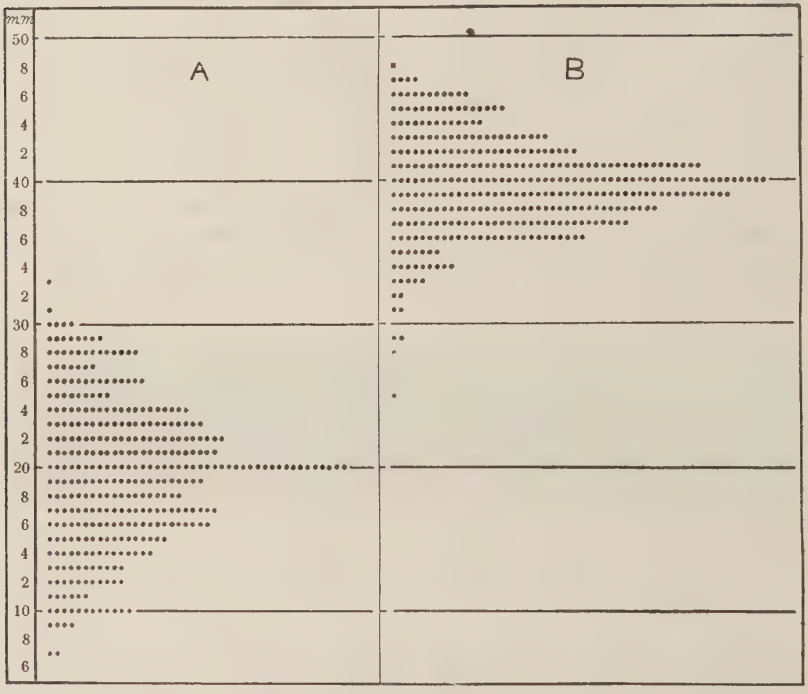


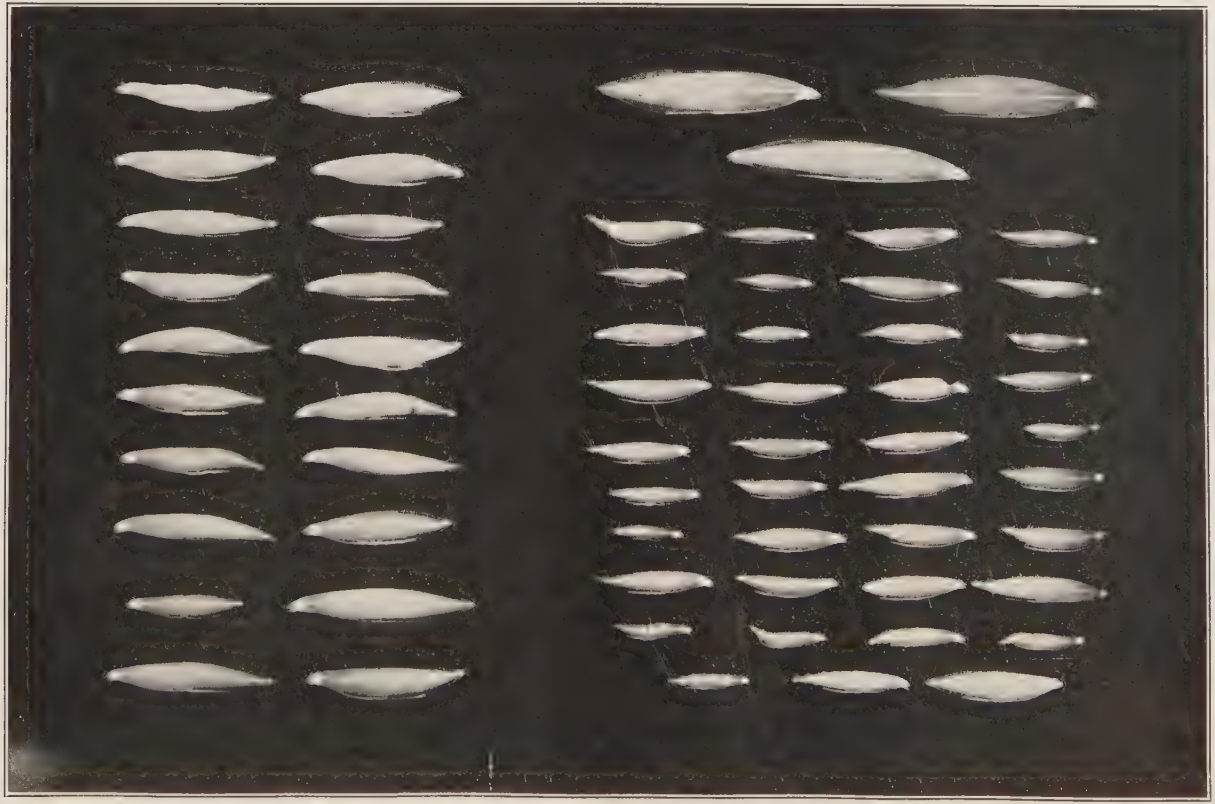
FIG. 14.—American Eel (*Anguilla rostrata*): sizes of larvæ in *April* (A) and *July* (B)

A. "Dana," Stat. 948, April 27, 1921, 22° 14′ N., 67° 22′ W.
B. "Dana," Stat. 891, July 24, 1920, 29° 28′ N., 69° 25′ W.

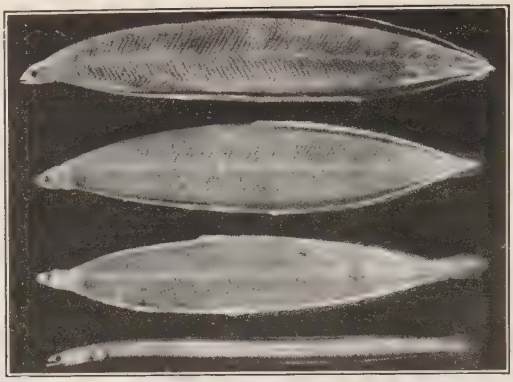
as many as 219 and 229 larvæ of the American eel at one haul (see fig. 14).

The curves on the charts (figs. 5 and 15) show the distribution of the larvæ of the American eel. The outermost curve marks the limit of occurrence, the next is that for 30 mm., and the innermost for 15 mm., to be understood as in the case of the European eel.

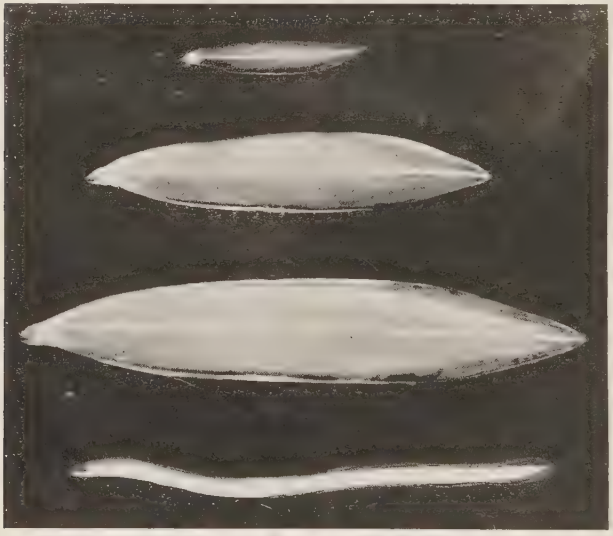
From the position of the curves we can conclude that the breeding area of the American eel lies along the entire range north of the West Indian Islands. Its central portion lies west and south of the central breeding grounds of the European eel; the areas embraced by



AMERICAN EEL (ANGUILLA ROSTRATA) AND EUROPEAN EEL (ANGUILLA VULGARIS) LARVAE FROM ONE HAUL AT "DANA" STATION 855 (LAT. 29° 15′ N., LONG 59° 45′ W.), DEPTH ABOUT 50 M., JUNE 8, 1920. SIMILAR HAUL TO THAT SHOWN IN FIG. 12. THE GROUP OF SPECIMENS ON THE LEFT ARE ANGUILLA ROSTRATA (ALL OF THE 0 GROUP). THAT ON THE RIGHT ANGUILLA VULGARIS (THREE OF I GROUP, THE REMAINDER OF 0 GROUP). REDUCED



1. AMERICAN EEL (ANGUILLA ROSTRATA). METAMORPHOSIS OF LARVAE. THE TOP SPECIMEN IS A FULL-GROWN LARVAE BEFORE METAMORPHOSIS, THE LOWER ONE AN ELVER. GULF STREAM AREA OFF THE ATLANTIC COAST OF THE UNITED STATES
Natural size. (From Johs. Schmidt, l. c. 1916)



2. EUROPEAN EEL (ANGUILLA VULGARIS). SHOWING THE SIZE OF THE FOUR YOUNGEST YEAR-CLASSES IN JUNE
About natural size

3. AMERICAN EEL (ANGUILLA ROSTRATA). SHOWING THE SIZE OF THE TWO YOUNGEST YEAR-CLASSES IN JUNE
Natural size

the two species, however, are apparently not separated, but seem to overlap.

The early tiny larvæ, 7–8 mm. long, of *Anguilla rostrata* were taken in February.[13] In April the average length was about 20–25 mm., in June about 30–35 mm., in July about 40 mm., and in September about 50–55 mm (cf. fig. 14). Toward the end of the year the larvæ have attained their full length, about 60–65 mm.; metamorphosis takes place during the winter months, and in spring the hosts of elvers move up into fresh water. We have examined samples of pigmented elvers from St. Croix, West Indies (March), from the Potomac at Washington (April), and from Little River, Mass. (May). The average length in the two latter cases was about 57 mm.

From the data to hand, then, we may conclude that the American eel spawns earlier, that its larvæ grow more rapidly (cf. fig. 14), and that the full-grown larva is smaller than is the case with the European species. A result of this is that *Anguilla rostrata* can complete its full development from egg to elver in about one year, whereas *Anguilla vulgaris*, as we have already seen, takes about three years. The photograph, Plate 6, Figure 2, in comparison with Plate 6, Figure 3, illustrates this, and shows that the I group of *Anguilla rostrata* in June are already metamorphosed elvers, while this stage of development is in the case of *Anguilla vulgaris* only attained by the III group. Despite the fact that the two species are outwardly so alike as to be hardly distinguishable, they differ to such an extent that the one takes about three times as long as the other to pass through the same cycle of development.

The recognition of this difference between *Anguilla rostrata* and *Anguilla vulgaris* is of decisive importance to the comprehension of the life history of the two species, and the fact provides a natural explanation of several points that seemed mysterious before.

As already mentioned, an investigation of samples of eels from Bermuda showed that they all belonged to the American species (*Anguilla rostrata*). This in itself was not surprising. But in the winter of 1913–14 both the *Margrethe* and *Bache* found the waters round Bermuda populated chiefly by larvæ of the European eel. I called attention to this point when dealing with the collections from the two vessels (cf. p. 295), but was obliged to confess that it was

[13] It is not easy to distinguish the two *Anguilla* species in their early larval stages, when the hindmost myomeres can not yet be counted with certainty. On an average, however, *Anguilla vulgaris* has a few preanal myomeres more than *A. rostrata*. In both species there are a couple of black chromatophores on the embryonic fin near the tip of the tail. As a rule, these are more pronounced and remain longer in *A. rostrata* than in *A. vulgaris*. In the latter they are often difficult to discern and seem always to disappear before the larva reaches a length of 20 mm.; in *A. rostrata* they are sometimes discernible at a length of 30–35 mm. In several larvæ the gut contained food consisting of minute organisms, presumably Coccolithophoridæ.

beyond my comprehension. Viewed in the light of our subsequent investigations, however, the explanation is perfectly simple. The larvæ of the European eel which are found at Bermuda and in the western Atlantic generally are, owing to the vicinity of the breeding grounds, all young, belonging to the O and I groups, and consequently as yet far from that stage of development at which they seek the shores. It is only larvæ of the American eel which are found so far west in the full-grown and metamorphosic stages, at which they are drawn to the coasts. Consequently, *Anguilla rostrata* is the only one of the two species which "lands" at Bermuda, the hosts of larvæ of *Anguilla vulgaris* which surround these islands being only passers-by on their way to a far more distant goal.

As we have learned, the breeding grounds both of the European and of the American eel lie west of longitude 50° W. Although the larvæ of *Anguilla rostrata* become far more numerous in proportion from east to west, it is nevertheless a fact that there are extensive areas where the larvæ of the two species are greatly intermingled. The *Dana* stations provide many examples of such intermingling, as shown in the photograph, Plate 5, and the graph, Figure 12.

It is very natural then to ask: If the larvæ of the two species are found greatly intermingled in certain areas of the ocean, how is it that the stock of eels in Europe is, practically speaking, pure, i. e., composed exclusively of *Anguilla vulgaris* and that in America of *Anguilla rostrata*? The question may also be formulated as follows: How do the masses of larvæ in the western Atlantic sort themselves out, so that those individuals which belong to *Anguilla vulgaris* ultimately find themselves in Europe, while those of *Anguilla rostrata* "land" on the shores of America and the West Indies?

In the main, the question is no longer difficult to answer. In the case of the American eel, the pelagic larval stage is terminated in about one year; consequently the larvæ have not time to make the journey to Europe, the distance being more than they can cover in that period. It is otherwise with the European eel, which takes nearly three times as long over its larval development, as a result of which practically all of them are far away from the western (American) portion of the Atlantic when the time comes for them, as elvers, to seek the coasts.

We can thus indicate both a geographical and an ethological cause for the distribution of the two species of fresh-water eels. The former lies in the fact that *Anguilla rostrata* has its center of production somewhat farther west and south than *Anguilla vulgaris*. The latter is the different duration of the pelagic migratory stage. These two facts, in conjunction with the ocean currents as an aid to transport, and later—once the earliest stages of development are past—the active movements of the larvæ themselves, must be regarded as

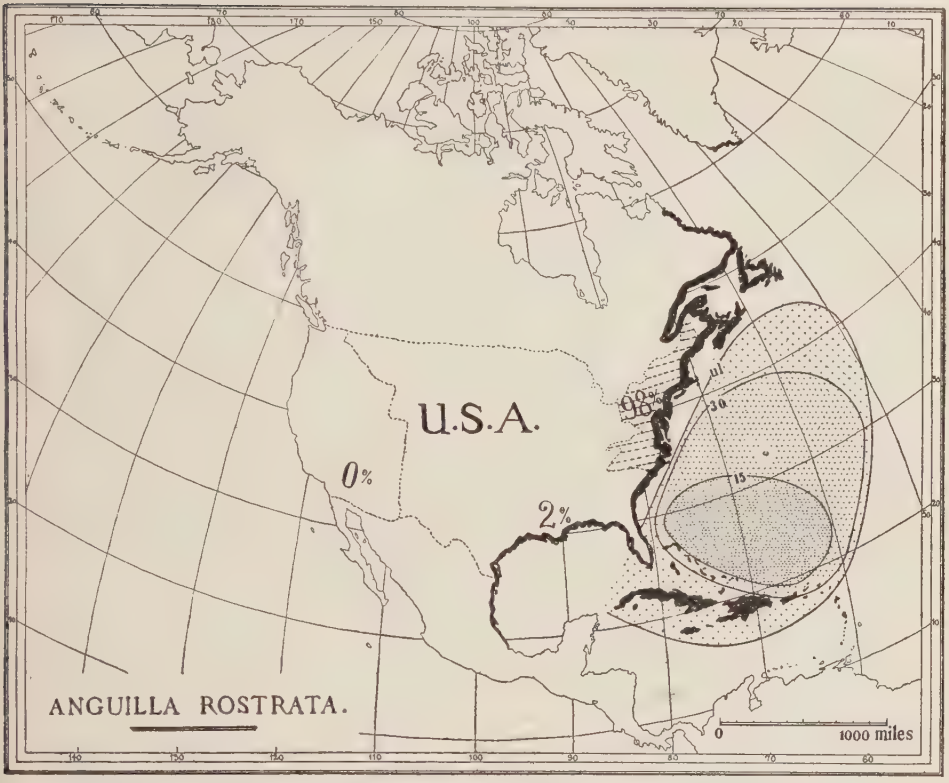


FIG. 15.—American Eel (*Anguilla rostrata*)

Distribution of larvæ (dotted area) and of adults (black strip along the coasts where the species occurs).

The curves show limits of occurrence; i. e., larvæ less than 15 mm. have only been found inside the 15-mm. curve, etc.; the outermost curve denotes limit of occurrence of unmetamorphosed larvæ (ul).

How does the distribution of the adult stages of *Anguilla rostrata* agree with the distribution of the larvæ?

Many years ago (Johs. Schmidt, l. c., 1909, p. 8) I tried to find a numerical expression for the density of eels in the United States, dividing the States into three regions: (1) Atlantic region (rivers draining into the Atlantic); (2) Gulf region (rivers draining into the Gulf of Mexico); (3) Pacific region (rivers draining into the Pacific).

Setting the product of the eel fisheries in the States in connection with these subdivisions of the region, we find that of the total product about 98 per cent comes from the Atlantic region, especially the northern States (North Carolina and northwards) and only about 2 per cent from the Gulf region (nothing from the Pacific) (cf. chart above).

This difference is so striking that we may conclude therefrom that there is a much greater run of elvers in the Atlantic region than in the Gulf region.

A glance at the chart above shows that the center of production for the larvæ of *Anguilla rostrata* is situated north of the West Indies (inside the 15-mm. curve) and that the larvæ during their increase in size spread out to the north and only to a smaller extent to the south. On our cruises we found masses of larvæ north of the West Indies and in the Gulf Stream region off Atlantic coasts of the States (cf. fig. 17), but comparatively very few south of the West Indies in the Caribbean Sea and in the Gulf of Mexico.

There is thus an excellent agreement between the density of eels in the United States and the results of our investigations regarding the breeding grounds of *Anguilla rostrata* and the direction of migration of its larvæ.

the causes which lead the two Atlantic species of eels to find each its own side of the ocean, despite the close proximity of their breeding grounds.

That fish should undertake migrations of considerable extent while in the pelagic larval stage is nothing unusual. I need only call to mind the young of the Gadoids and their migration round Iceland, which I had an opportunity of studying in 1903–1905 (loc. cit., 1909). The point which makes our eel an exception among fishes, and among all other animals, is the enormous extent of its journeyings in the larval stage. This is indeed a migratory stage par excellence, the unusual duration of which must be regarded as an adaptation—effected by selection—to the distances of many thousand miles to be traversed. So great are these distances that the class of one year can not reach its goal, the fresh waters of Europe, until a second and a third have started on their way. As a matter of fact, we have in early summer three year-classes of larvæ on their journey; the youngest in the western, the next in the central, and the oldest in the eastern waters of the Atlantic, off the coastal banks of Europe (cf., pl. 6, fig. 2, and fig. 7). There can be no doubt that a great wastage of individuals takes place in the course of these years of migration, but it is in all probability insignificant in view of the enormous production of larvæ, of which the *Dana* stations in the western Atlantic give evidence.

The *Anguilla* species, in contrast to other murænoids, are usually termed fresh-water eels, and are reckoned among the fresh-water fishes of Europe and North America. From what we have now learned this is far from literally strict. Both from their history and their actual manner of life, these "fresh-water eels" are true oceanic fishes, and the remarkable point in their life history is not so much the fact of their migrating out into the sea to spawn as in their leaving it in order to pass their period of growth in an environment so unusual for murænoid fishes as fresh water.

I have in the foregoing pages described the course of our investigations and set forth their results. In conclusion I will endeavor very briefly to give an outline of the life history of our eel, as indicated by the facts now ascertained.

During the autumn months the silvery eels leave the lakes and rivers and move out into the sea. Once beyond fresh-water limits the eels are, in most parts of Europe, outside our range of observation. Exceptions are, however, found, as in the case of the Danish sounds and belts and adjacent waters, which are passed by great quantities of eels on their way to the Atlantic, and form the site of

important fisheries about October. In the western part of the English Channel trawlers may, toward the end of the year, occasionally bring up a few big specimens in their nets, but after this the last trace of the eel on European ground is lost. No longer subject to pursuit by man, hosts of eels from the most distant corners of our continent can now shape their course southwest across the ocean, as their ancestors for unnumbered generations have done before them. How long the journey lasts we can not say, but we know now the destination sought: A certain area situate in the western Atlantic, northeast and north of the West Indies. Here lie the breeding grounds of the eel (fig. 6).

Spawning commences in early spring, lasting to well on in summer. The tiny larvæ, 7–15 mm. long, float in water layers about 200–300 meters from the surface, in a temperature of about 20° C. The larvæ grow rapidly during their first months, and in their first summer average about 25 mm. in length (fig. 11). They now move up into the uppermost water layers, the great majority being found between 50 and 25 meters or at times even at the surface itself. Then they commence their journey toward the shores of Europe, aided by the eastward movement of the surface water itself. During their first summer they are to be found in the western Atlantic (west of 50° long. W.). By their second summer they have attained an average length of 50–60 mm., and the bulk are now in the central Atlantic. By the third summer they have arrived off the coastal banks of Europe and are now full grown, averaging about 75 mm. in length, but still retaining the compressed, leaf-shaped larval form. In the course of the autumn and winter they undergo the retrograde metamorphosis which gives them their shape as eels and brings them to the elver stage, in which they move in to the shores and make their way up rivers and watercourses everywhere (Plate 3). The average age of the elvers in spring is about 3 years. Many individuals, especially males, keep to the brackish water in lagoons or estuaries; others, especially females, move far up the streams they have entered and may in the course of their wanderings penetrate far into the interior of the Continent. In Switzerland, for instance, considerable quantities of eels occur, and specimens have been taken there in waters at an altitude of 3,000 feet above the level of the sea. The eels utilize their sojourn in fresh water to feed and grow big, but the duration of their stay here varies greatly, according to sex, climate, and quantity of food, ranging from about five to about twenty years or more. All the large eels are females; the males seldom exceed 45 cm. in length. During its period of growth the eel is of a yellowish or greenish color, with no metallic luster; these growing eels are generally termed "yellow eels." When they have reached the stage

where the migratory instinct begins to assert itself the desire for food, otherwise voracious, is lessened, the body takes on a metallic sheen, and the pectorals become black and pointed. In this guise the ells are termed "silver eels," their flesh is very firm and rich in fat, and they are thus well equipped for entering upon their second and last great journey, this time back to the breeding grounds across the ocean.

Before concluding this survey of the Danish eel investigations it is my pleasurable duty to thank all those who have contributed to the progress of the same. I have already mentioned how decisively important was the aid afforded us from outside. Special thanks are here due to Admiral H. R. H. Prince Valdemar, of Denmark, and to His Excellency H. N. Andersen, director of the East Asiatic Co., of Copenhagen. But in our Commission for Investigation of the Sea also, much, and most valuable work has been done to further these investigations first and foremost by the chairman, Commodore C. F. Drechsel, Danish R. N.

Last, but not least, I thank my assistants who helped to carry out the actual work at sea and on land. These, during the first years, A. Strubberg, M.Sc., later P. Jespersen, M.Sc., and Å. V. Tåning, M.Sc., have each taken a great share of the work with much skill and enthusiasm. Further, the captain of our research vessel, Capt. G. Hansen, has, in addition to the other duties falling to his share, on more than one occasion carried out work on board which called for training in marine biological research.

POSTSCRIPT

Do the Indo-Pacific fresh-water eels breed in the sea like those of the Atlantic, and do they, like these, undergo a larval development with metamorphosis?

The present work has up to now considered only the two Atlantic species, the European and the American eel.

There are, however, in the Indo-Pacific region also fresh-water eels of the genus *Anguilla*, and, moreover, many more species than in the Atlantic area.

What is the life history of the Indo-Pacific eels?

Do these eels breed in the sea, like the two Atlantic forms; have they similar larval stages; and do they, like those of the Atlantic, undergo a retrograde metamorphosis from larva to elver?

Nothing is known as to this. And even if we had larvæ which might be supposed to belong to one of the Indo-Pacific *Anguilla* species, they could not be identified from what is generally known, as the information afforded by extant literature as to classification of the Indo-Pacific eels is insufficient. The limits of the different

species can not be defined, either zoologically or geographically, without further characters than hitherto employed in classification.

It was therefore necessary to take up the whole question anew.

I have for several years been working on the classification of the Indo-Pacific fresh-water eels, but have only lately been able to give it full attention.

Thanks to the courtesy of the various authorities, I have been able, with my assistants, especially Mr. Vilh. Ege, M. Sc., to examine the material of Indo-Pacific *Anguilla* specimens of most of the leading museums, and get X-ray photos of most of the existing type specimens. I have also received large collections from correspondents in various parts of the world.

In all specimens, the number of vertebræ was determined, and other numerical characters investigated; several species have already been treated statistically, as previously with the Atlantic and Japanese.[1]

The investigation shows that the previous classification is inadequate. Take for instance, the *Anguilla australis*, originally described by Sir John Richardson. This species, as understood by the most recent writers on Indo-Pacific eels, ranges from East Africa to Tahiti, and from the Philippines to Auckland Island. Geographically, this looks improbable, and on applying numerical characters we find that "*Anguilla australis*" consists of at least three well-defined species, each with its own geographical area.

The introduction of numerical characters, however (number of vertebræ, fin-rays, etc.), is of importance not only for classification of old, adult eels. We have thereby procured the means, hitherto lacking, of identifying the early stages of the Indo-Pacific fresh-water eels.

The method has already borne fruit, in that I am able here to describe and identify the first larva of an Indo-Pacific *Anguilla* species, and thus answer the question at the head of this postscript. I am the more pleased to be able to do so here, since the material was procured by an American expedition.

Some years back, I received from the Bureau of Fisheries at Washington a large collection of Leptocephali for investigation. It was collected by the U. S. S. *Albatross* on its Philippine expedition (1907–1910) under Dr. Hugh M. Smith.

This collection proved to contain two specimens of a Leptocephalus outwardly altogether identical with the larvæ of the two Atlantic *Anguilla* species. They were taken near the surface over consider-

[1] Johs. Schmidt: "First Report on Eel Investigations" and "Second Report on Eel Investigations" ("Rapports et Procès-Verbaux du Conseil International pour l'Exploration de la Mer," vol. 18, 1913, and vol. 23, 1915). See also Figure 1 in the present work.

able depths off Celebes, one near Menado on the north coast, the other in the large Tomini Bay on the east coast. The lengths were 53 and 55 mm. Both specimens were preserved in formol and well enough for sufficiently accurate determination of the numerical characters. Reserving detailed description for a later occasion, I will here refer to Figures 1 and 2, plate 7, and give the following data. determined by Mr. A. V. Tåning, M Sc.

The specimen of 53 mm. is a fully developed larva, metamorphosis not yet begun, larval dentition intact, 16–17 teeth in each half of jaw behind the large grasping teeth; in other words, about the same number as in *A. vulgaris* and *rostrata*. It has 106 (69+37) myomeres, answering to 105 vertebræ, 285 dorsal, 218 anal, and 10 (5+5) caudal rays.

The other specimen, 55 mm. (more correctly 55.5 mm.) has begun metamorphosis and lost the larval teeth. Number of myomeres about the same as in the first larva, about 106; like the Atlantic species at the same stage, it has some black stellate chromatophores at tip of tail.

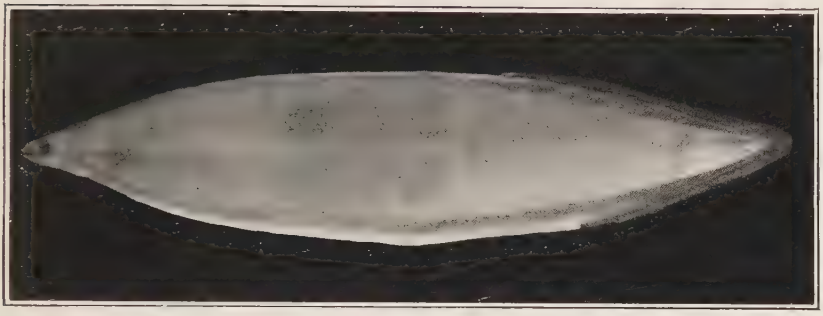
The numerical values of the larvæ enable us to identify them, at least the first specimen, with sufficient certainty as belonging to the species *Anguilla mauritiana* Bennett, a widely distributed tropical species, common in the Dutch East Indies. These values agree completely with those we have found in *Anguilla mauritiana*, and preclude other species, especially the two common in this area—*Anguilla australis* Autt. and *Anguilla celebesensis* Kaup. The advanced position of the dorsal fin in our larva (fig. 1, plate 7) also shows that it belongs to *Anguilla mauritiana*.

The identification of the larvæ from Celebes reveals several interesting points which I will briefly note here.

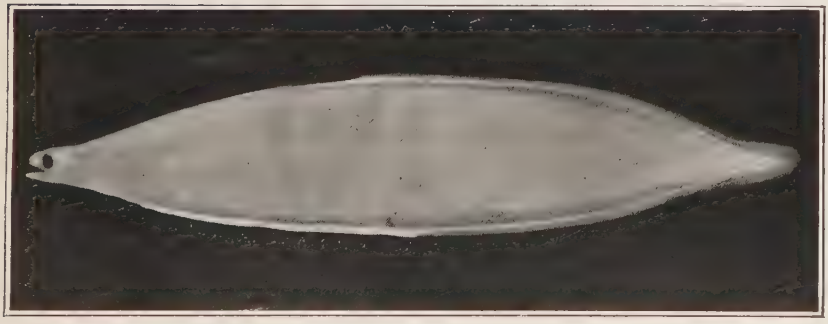
1) We have learned that the larvæ of Indo-Pacific fresh-water eels entirely resemble those of the Atlantic species. This is a further proof of the extremely close relationship between all *Anguilla* species, for *Anguilla mauritiana* is probably one of the forms most widely removed from ours.

2) The length of the *Anguilla mauritiana* larva is about 5½ cm. This agrees well with the average length of five elvers of this species from the Dutch East Indies (Zool. Mus. Amsterdam), about 5 cm.

3) The identification of the larva of *Anguilla mauritiana* is an incontestable proof that the Indo-Pacific *Anguilla* species, like the Atlantic, breed in the sea and undergo a larval development with metamorphosis. Other facts which I have brought to light show that the Indo-Pacific fresh-water eels, like those of the Atlantic, require deep water to breed. I will deal with this point in a subsequent paper.



1. ANGUILLA MAURITIANA BENNETT—LARVA BEFORE METAMORPHOSIS (LENGTH, 53 MM.)



2. ANGUILLA MAURITIANA BENNETT?—LARVA IN METAMORPHOSIS (LENGTH, 55 MM.)

Both specimens were caught near the island of Celebes, Dutch East Indies, by the U. S. S. Albatross in November, 1909

CANKERWORMS

By R. E. Snodgrass,
Bureau of Entomology, United States Department of Agriculture

Language is replete with terms that liken qualities of human nature with the traits of animals, and fable writers of all times have found an inexhaustible source of material for their stories in the parallelisms between men and beasts. The insects, too, have served in caricature as types of human character, though less accurately, since they are less understood; for even amongst them there are the bold and the timid, the haughty and the meek, the nervous and the phlegmatic, the obstreperous and the patient; there are those that labor incessantly and those that accept conditions as they find them; there are the pugnacious, always looking for trouble, and those that live by avoiding it; there are the rapacious that seek the destruction of others, and the peace-loving, who fight in defense only.

Distinctions of this kind amongst animals, as amongst people, are matters of temperament, but there is this difference between the two cases in that, with people, temperamental traits are characteristic of individuals, while, with animals, the differences are largely characteristic of the species. Yet there are minor differences between individual animals, and people also show strongly marked racial traits of temperament which persist and intensify where races do not commingle.

At first thought we might not believe that the temperaments of animals, and especially of insects, could have any relation to our own other than an accidental resemblance. On second thought, however, it seems entirely possible that all such manifestations may be identical in the sense that they may be but outcroppings of a common property inherent in living matter itself. Temperament is merely the reaction of the individual to external conditions, and with people who exercise no control over these reactions, temperamental exhibitions may be just as spontaneous and irresponsible as with insects. In many cases amongst animals a specific temperament is beneficial or is a necessary accompaniment of a special mode of life. A predatory creature must be alert, quick of movement, and aggressive; a vegetarian may be slow and placid, with a de-

fensive but not an offensive nature; an animal that lives in concealment may be sluggish and lacking in all kinds of positive personality.

It is always a matter of wonder to me to see enthusiasts of sport standing in line for hours and hours in order to get desirable seats at some athletic contest, or lovers of the spectacular waiting on the curb of the sidewalk from early in the day to be sure of a place in the front line of spectators when a procession is to go by. I realize, however, that their temperaments are different from mine, not in that they enjoy the sport or the spectacle more than I do, but in that they are able to stand there so long waiting to see it. The secret is that standing and doing nothing does not distress them; they are still normal at the end of it, because it is normal for them to be that way. So when we see animals, especially insects, doing what would be torture to our patience we have only to realize that their temperaments are different, and that the thing does not distress them, because it is normal for them to go through with it.

FIG. 1.—A female spring cankerworm moth resting on dead spur of an apple tree (× 2½)

In early spring those insects that must always be in time for the first course in nature's seasonal banquet begin to arrive at the feeding grounds. Nature, however, assumes no responsibility of calendar dates; the guests may be present, but if bad weather takes precedence, the food will not be served till warmer temperatures prevail. The guests must wait with empty stomachs. As above intimated, though, "patience" is a term not to be applied to insects literally, since it implies voluntary submission to irksome necessity. With insects, passive endurance is a physiological state, a matter of constitutional temperament. But is it not so with patient people, is not their placidity due to constitutional physiological conditions that allow them to be so? A person undergoing an operation under an anesthetic is a "patient" only in the technical terms of the hospital; an insect quietly submitting to adverse conditions of its environment is submissive because it lacks a stimulus to be otherwise, it is under a physiological anesthetic.

Among the earliest of the spring arrivals in the Northern States and in Canada are curious little insects that come out of the ground, sometimes during warm spells in January and February, but mostly during March and April. They are to be found

particularly in old neglected apple orchards where insects have been allowed to lead their lives unchecked, and in elms along city streets and in parks and woodlands. They are most easily discovered sitting on the trunks of the trees, where eventually they make their way after leaving the earth. Here they often remain at one spot all day or for several days, especially if the weather should turn bleak and raw, as it is likely to do during March and April, especially in the more northern latitudes, somtimes with cold rains, and freezing temperatures at night, and sometimes with snow yet on the ground.

A gray spot against the bark of the tree trunk, on closer inspection, proves to be a living thing with an oval, furry body about half an inch long, six long sprawling legs, a pair of slim antennæ, and two large black eyes (fig. 1). It curiously suggests a moth with the wings cut off, and, indeed, no better simile is needed, since the creature is a moth with its wings so reduced by nature that but stubs of them remain (fig. 2). Entomologists know this insect as the female moth of the spring cankerworm (*Paleacrita vernata*).

Fig. 2.—Female moths of spring cankerworm, in active attitude above, in resting position below (× 2½)

An insect that comes out at such an unseasonable time of the year can not expect to find anything to eat; and, in fact, the cankerworm moth has no such expectations, her business is of quite a different nature. She comes bearing a load of eggs which are to produce her offspring, and she must deposit these eggs on the tree sufficiently in advance of the time when the leaf buds will open to allow the young to develop and be ready to hatch when their food is ready, because the offspring of this moth will be a brood of hungry, leaf-feeding caterpillars. The mother moth, therefore, has no concern for herself; for the sake of her progeny she endures all the hardships of weather that may come at this season, low temperatures, chilling winds, soaking rains, perhaps snow. Few other insects could endure unprotected what the cankerworm moth habitually encounters, which again demonstrates the physiological differences that may exist between closely related creatures, and which cause them to react very differently to the same external conditions.

The oval body of the cankerworm moth is little more than a bag of eggs. In the forward parts there are the muscles necessary for

moving the legs and for enabling these members to drag the heavily loaded body over the ground and up the tree, and of course there are breathing tubes, nerves, and a heart, all of which organs are necessary for existence. But the alimentary canal is reduced to a mere thread, and the external organs for taking food are so rudimentary as to be entirely useless, the material necessary for maintaining the life of the moth and for maturing the eggs having been stored in the body of the insect during her own caterpillar days.

The exterior of the body of the moth appears to be covered with a thick coat of fur, but, as with all moths, the material is really a close growth of slender scales, which, however, are but modified hairs. On the back of each of the seven exposed segments of the abdomen there are two crosswise rows of recumbent spines directed backward.

FIG. 3.—Male moth of spring cankerworm (× 2½)

From the rear end of the body the spring cankerworm moth can protrude a long tapering tube made of the terminal body segments, which are ordinarily retracted one into the other like the sections of a telescope. The eggs are extruded from the end of the tube when the tube is extended.

For a long period, sometimes for several days, the female moth sits on the trunk or on a lower limb of the tree quietly waiting, perhaps not knowing why, but events suggest that she is waiting for a mate. At any rate, a male moth (fig. 3) eventually comes to her; he comes fluttering on large wings, for in respect to organs of flight he has not lost his insect heritage, though he too lacks organs for taking food. After a brief time of courtship and mating the male departs, and the deserted female is left to finish her life in solitude as she began it. But now, in addition to her eggs, she carries the fertilizing element of the male, without which the eggs would be useless. The female soon resumes her journey upward and outward on the branches of the tree, searching for suitable places at which to deposit her eggs.

When the egg-laying tube of the female is fully extruded it is about as long as half the rest of the body. With its tip the moth probes into crevices or beneath pieces of loose bark, and when an appropriate place is located she deposits there a group of eggs (fig. 4). Moths that were taken into a room for observation during egg laying curved the egg tube forward beneath the body and ejected the eggs forward and downward from its tip; and the position of the eggs in

most clusters found on the trees indicates that they must have been placed in this same manner. Others, however, are deposited so far under a ledge of bark that the moth must have entered the cavity in order to have reached its innermost recesses with her egg tube. Her habit of probing forward suggests that in such cases she backs over the edge of the piece of loose bark and enters the cavity upside down. The purpose of the spines on her back is not evident. Though they may protect her body in tight places, it would seem that they would also impede her entrance into crevices. The spines are present likewise on the same segments in the male, but are somewhat weaker than in the female.

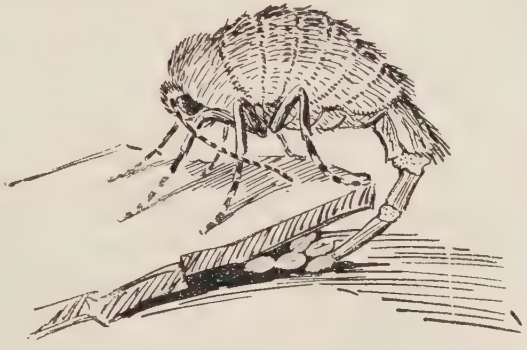


FIG. 4.—Female moth of spring cankerworm depositing eggs in crevice beneath piece of loose bark

The eggs of the spring cankerworm (fig. 5) are to be found on the trunk, on the limbs, and on the twigs of the trees. Usually they occur in groups of 30 to 60, though as many as 150 have been recorded in one mass, and often there are but three or four together. Dr. S. J. Hunter, writing of the spring cankerworm in Kansas, says that a dissection of 12 moths gave an average of 401 eggs in each, an exceptional individual containing 676 eggs. A count of the actual number of eggs laid, however, he says gave an average of only 81 for each moth, but these records were made from moths of a brood below normal vitality. The eggs of the spring cankerworm are oval in shape, rounded at one end, slightly pointed at the other, and are about one thirty-sixth of an inch in length. The shells are soft, easily dented, and are marked by fine lengthwise lines; those of some groups are brownish, others are greenish, but all are iridescent with pink and green reflections. The eggs lie in jumbled masses, all stuck to the bark or to one another, some flat on their sides, others inclined or standing on end.

FIG. 5.—Group of eggs of spring cankerworm moth beneath projecting piece of bark (much enlarged)

When the moth has deposited her eggs her brief life's work is over. She falls back to the earth and there lies until her vital forces are dissipated. Yet the eggs within her egg tubes previous to laying had no connection with her body; being freed from their weight, it would seem, should be a relief to her and not an exhaustion. Here

again, by some unknown physiological regulation, life soon ceases after its purposes are accomplished.

Early in May, usually about the time the buds on the apple trees are opening and sending out the new leaves, the cankerworm eggs hatch and send out a destroying army of young caterpillars. According to Doctor Hunter, the time of hatching depends on the temperature. Eggs kept in the laboratory with a temperature of 72°, he says, will hatch in 10 days; eggs under outdoor conditions with a mean temperature of 48° hatch in 30 days. Each caterpillar, or cankerworm, leaves the egg through a round hole in the blunt end, and, as it emerges, assumes a length of about one-eighteenth of an inch, fully twice that of the egg from which it comes out. The empty shell remains as a delicate, transparent capsule glistening with its iridescent colors. The young caterpillars are snaky-looking little things, despite their large heads and flaring hind legs (fig. 6); but their curious manner of walking by humping up the back as the rear end of the body is brought forward, and then straightening out again to repeat the humping, at once catches the eye, and we recognize in the tiny creatures familiar acquaintances—*measuring worms!*

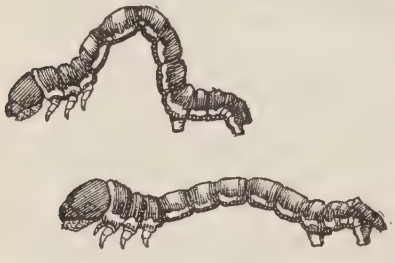


FIG. 6.—Newly hatched spring cankerworms (much enlarged)

Some of the young worms are blackish, others are brown or green, but most of them are marked by a narrow yellow stripe along each side of the body. Their special feature, however, which gives them the snaky look just mentioned, is the lack of most of those legs on the abdominal segments that are ordinarily characteristic of caterpillars. The form and structure of a typical caterpillar was described in the Smithsonian Report for 1922 (p. 353, fig. 17, A), where it was shown that the caterpillar body consists of 13 segments, the first 3, or thoracic segments, carrying each a pair of jointed legs, while of the remaining 10 or abdominal segments, the third to the sixth, inclusive, and the tenth have each a pair of soft, thick, unjointed "*prolegs*." The spring cankerworms have prolegs only on the sixth and tenth segments. Hence their looping method of walking.

The full-grown spring cankerworms (fig. 7) are from three-fourths of an inch to a full inch in length. In general they are of a dark color, but they vary from pale olive brown or yellowish to mottled brown and black, with one, two, or three broken yellowish lines more or less distinct along the sides. On the back of the eighth

abdominal segment there is a pair of small tubercles. There are always only two pairs of abdominal prolegs as described above.

In observing cankerworms on an apple tree or in collecting specimens, however, it will most likely be noticed that they are not all alike. Some have the characters of those just described, while others are marked often by several distinct lines along the sides of the body, but are definitely separable as different by the presence of an extra though a small pair of prolegs on the fifth segment of the abdomen, which is the segment next in front of that bearing the first pair of fully-developed prolegs. Caterpillars of this sort (fig. 8) belong to a distinct species known as the fall cankerworm (*Alsophila pometaria*) because the moths that produce them appear mostly in late fall and deposit their eggs on the trees at this season. The eggs of both species hatch at the same time in the spring.

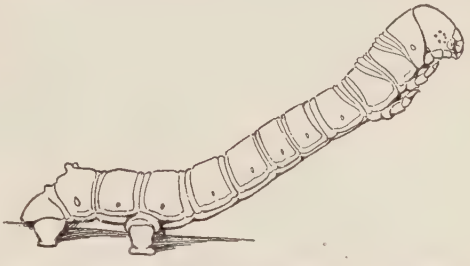


FIG. 7.—Mature spring cankerworm in resting attitude, showing lack of abdominal prolegs except those on sixth and tenth abdominal segments (× 2½)

The fall cankerworms are in general of a greener color than the spring cankerworms, but different individuals vary from light green to dark olive brown. Most of them have three distinct pale stripes along each side of the body, and an occasional one has a large blackish spot on each side of each segment between the lower two lines.

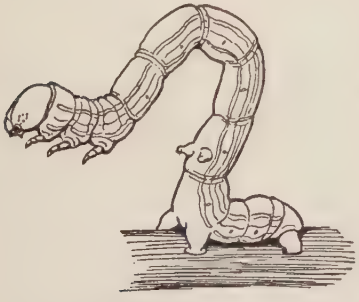


FIG. 8.—Mature fall cankerworm, showing presence of rudimentary prolegs on fifth abdominal segment

For a month the caterpillars of the two species of cankerworms feed together in the trees, where to the casual observer they all look alike, both kinds having the same general appearance and size and the same looping gait. They both, also, when at rest have the queer habit of grasping a twig or leaf firmly with the abdominal feet and holding the body stiffly in the air, projected at an angle from the support. They pose motionless in this attitude indefinitely and appear to be impersonating a dead twig in order to fool their enemies. They *may* sometimes elude the searching eye of an entomologist or of a bird, but still the habit can not be of any great benefit to the cankerworm species, since a bird could always find plenty of active individuals feeding unconcerned. The trait, however, is one

common to many other measuring worms and in its origin perhaps was beneficial. A habit more clearly protective is that which the caterpillars possess of letting themselves drop suddenly at the ends of threads from their spinnerets when a branch on which they are feeding is lightly jarred, and of hanging suspended in midair. After

FIG. 9.—Spring cankerworms in various attitudes on twigs of apple trees

a time, when no danger seems to threaten, they ascend their threads and resume feeding.

The cankerworms feed on several species of trees, but their favorite kinds are apple and elm. Wherever the worms have fed on apple leaves the scars become bordered by reddish brown areas, which, spreading over the uneaten parts, give the leaves the scorched appear-

ance characteristic of cankerworm injury. The very young worms make mere pits or punctures in the leaves, but the older ones devour great holes in them, finally reducing them to ragged skeletons or bare stems (fig. 10). The damage done to apple trees may be very considerable in cases of bad infestation, if remedies are not applied, but the orchardist can control the pest by thorough spraying with arsenate of lead, which, however, to be most effective should be done when the worms are young. In orchards that are known to be infested with cankerworms, the trunks of the trees may be banded in late fall and early spring with sticky substances or with cotton batting, in order to prevent the female moths from ascending them.

FIG. 10.—Apple leaves destroyed by cankerworms

So similar are the two species of cankerworms, both in the larval and in the adult stages, that even entomologists did not distinguish between them for nearly two hundred years after they were first called cankerworms. The name "cankerworm," however, did not originally belong to either of the two species of caterpillars to which we now apply it in America. At the time the English translation of the Bible was made, the word "canker" referred to most any destructive caterpillar.

Besides the cankerworms there are numerous other species of measuring worms, or spanworms, as they are also called, most of them having the same general appearance as the cankerworms. Some are well-known pests on cultivated trees and shrubs, and others are met with only occasionally, looping along in solitude or projecting motionless from a twig or the edge of a leaf. The majority of

them belong to a family of moths known as the Geometridæ, so named from the measuring habits of their caterpillars. The reduction of the abdominal legs of the caterpillars is an accompaniment of the looping style of progression, but does not occur to the same degree in all species. In one group of the family the caterpillars retain the full number of prolegs, which is five pairs, but the first three pairs are reduced in size (fig. 11), the first pair being very small, the others successively larger to the fourth pair, which is of ordinary proportions. These caterpillars probably represent an

FIG. 11.—A geometrid caterpillar (*Brephos infans*) having the full number of abdominal prolegs, but with the first three pairs reduced in size (×2½)

early stage in the evolution toward suppression of the first three pairs of abdominal legs. The fall cankerworm, with a rudimentary third pair of prolegs (fig. 8), is in a stage near the other end of the series, while the spring cankerworm (fig. 7) and others that retain only two pairs represent what appears to be the degree of leglessness most practical for the looping gait. All measuring worms, however, do not belong to the Geometridæ, the familiar cabbage looper being a member of quite a different family, the Noctuidæ.

When the cankerworms are full grown, about the 1st of June, they cease their feeding and let themselves drop from the trees at the ends of threads run out from their spinnerets. On reaching the ground they burrow into the earth and bury themselves at a depth of from 2 to 5 inches beneath the surface. Here the spring cankerworms, after from four days to a week, change to pupæ (fig. 12). The fall cankerworms, however, after their burial is accomplished, inclose themselves in small oval cases or cocoons made of earth particles firmly bound together with threads of silk, and then rest in the cocoons for about 30 days before changing to pupæ. The pupæ of the spring cankerworms remain in the ground through the summer, fall, and winter, transforming early the following spring into the moths which come out at this season and whose history has been given. Most of the pupæ of the fall cankerworm undergo their final transformation late in the fall of the year of their interment.

FIG. 12. Pupa of spring cankerworm in the ground (× 2½)

The nature of the pupa of a caterpillar and its metamorphosis to the moth was described in connection with the tent caterpillar in the Smithsonian Report for 1922 (p. 253, fig. 17.) It was

noted there that the reduction of the jaws, which organs are large and strong in the caterpillar and rudimentary in the moth, takes place by two steps, the first in the change from the caterpillar to the pupa, the second in that from the pupa to the moth. The wings of the female cankerworm moth undergo likewise their final reduction during the change from the pupa to the moth, but since the caterpillar is wingless, the wings appear first on the pupa, where they form fairly large pads as in the pupæ of moths that are to have fully developed wings. We might ask why wings are formed at all when they are only to be reduced again. The answer is that the maternal ancestors of the modern cankerworms were fully winged, and that the pupa in acquiring wings is but repeating the evolution of the species.

The tendency to wing reduction in the female moths of the Geometridæ, like the tendency to leg reduction in the caterpillars, appears to be a physiological proclivity of the family; it crops out in various degrees of expression in different species, though in some species both males and females are fully winged. The female of a species called the half-winged geometer (fig. 13, B) has wings of about half the normal size, appendages probably useless, but showing that the moth has reached a halfway stage in the evolution toward winglessness. In another species, known as Bruce's measuring worm, the female (fig. 13, A) resembles the females of the cankerworms but has wing rudiments a little longer. It is difficult to imagine just what such innate tendencies within a group of animals may be in terms of physiology, yet many other examples of the same thing might be given among insects and other animals, just as we note among ourselves family traits and family tendencies with regard to physical as well as temperamental characters. But again, wing reduction in moths, like leg reduction in caterpillars, is not limited to the Geometridæ, the female of the common tussock moth being as nearly wingless as the female canker moths.

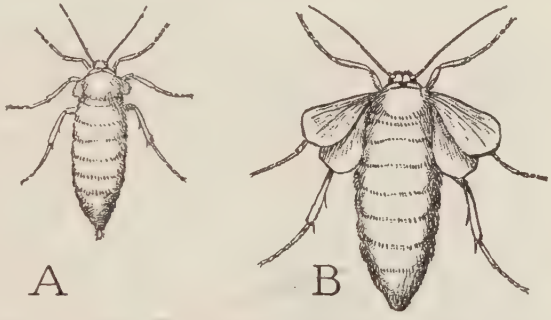


FIG. 13.—Female Geometrid moths with wings in different degrees of reduction. A, moth of Bruce's measuring worm (*Bachela bruceata*) having wings a little larger than the cankerworm moths; B, moth of the half-winged geometer with wings nearly half the normal length (× 2½)

Summer passes, fall comes, the first of November arrives. The place is southern Connecticut. The days are again cold and bleak.

The advance winds of winter come surging over the hills in the west; drenching rains soak the chilling earth and make sodden masses of summer's refuse that covers it. Now is the season when most of the insects that will survive till spring are stowed away in their cocoons or have found protection in some retreat where they will await the return of warmer weather.

Yet, seeming to defy the laws of the insect world that impose torpidity on other six-legged creatures and keep them in hibernation through the winter, the moths of the fall cankerworms now break through their cocoons and emerge from the earth. Some law of their own impels these creatures to undergo their transformation and to deposit their eggs at this inclement season—eggs which are not to hatch until the following spring. Any such striking example of exceptions to general rules shows clearly that the nature of the reaction by living things to external stimuli depends on the inner nature of the creature itself; the potency for individuality of physical temperament in living matter again asserts itself.

FIG. 14.—Female moth of the fall cankerworm (× 2½)

The female moths of the fall cankerworms (fig. 14) are very similar to those of the spring species in size and general appearance, though they are usually of a more uniform light brown color. They may be easily distinguished from the spring canker moths, however, by the lack of spines on the abdominal segments, and by the short length of the terminal hidden segments, which do not form a protrusible tube for egg laying.

From the places where they leave the earth, the wingless moths crawl through the grass and over the dead leaves that cover the ground until they arrive at the trunk of a tree. In cases of unusual abundance of cankerworms the moths may be observed in large numbers as they issue from the earth. Dr. S. J. Hunter, describing the emergence of spring cankerworms in Kansas in 1917, says: "Around the base of the large elms, and for several feet away the ground appeared to be moving, so abundant were the insects; and as these moved up the trees others kept emerging from the ground in such numbers as to form a regular procession." Furthermore, he adds: "The insects ascend, apparently alike, all standing objects. Bands on maple trees caught as many as bands on adjoining trees. The same can be said of telegraph poles or stone hitching posts."

Ordinarily, however, the insects are too few in numbers to be often observed in transit from the places of emergence to the tree trunk; and whether in such cases, under variable weather conditions, the journey is long or short, whether it involves a devious search, whether some sense or instinct unerringly guides the travelers, or whether many miss their destinations, has not been determined. The writer, however, once marked four active fall canker-worm females with spots of white water-color paint and placed them on the ground on four sides of an apple tree at 4, 6, 7, and 8 feet, respectively, from the base of the trunk. On the sixth day following, which was the 1st day of December, one of the marked individuals was found on the trunk of the tree, about 2½ feet above the ground. The one placed at 7 feet had been missing for five days. During these five days, then, she had made the journey of 7 feet over the ground. The night after she was missed from the starting point a light snow fell and lay on the ground most of the next day. The succeeding days were bright, though cold and raw. The other three moths were still at or near the places where they had been set out. Several more females were then marked in a similar manner and placed beneath trees, but only the one just described was ever recovered. This one, during the afternoon of the day of her arrival on the tree trunk, moved a foot and a half higher and then remained at this point until 11 o'clock on the morning of the following day. After this she was seen no more, probably having continued her journey up the trunk and out on one of the branches of the tree. Many of the females wait a much longer time on the trunk of the tree before proceeding upward. Some sit in one spot through several days and nights. Whether they are detained by unpropitious weather or whether they wait for a male was not determined. Only one pair of mated moths was observed, and they were found about 10 o'clock one morning on the upper end of the trunk of an apple tree.

FIG. 15.—Male moth of the fall cankerworm in resting position on a twig (× 2½)

The males of the fall cankerworm (fig. 15) resemble the males of the spring cankerworm, though they are more yellowish-brown in color, and have the outer margin of each fore wing marked with a pale grayish spot toward the tip. In Connecticut, they may frequently be seen on warm afternoons of November fluttering along the roadsides or flitting about in the orchards. A male canker moth

flies in a very uncertain manner, first going off on a wavy course, up and down, or edging along without making much headway, then perhaps holding a sustained flight for several yards, finally to bring up precipitously in a tree or shrub as if the effort had taken the last bit of his strength. Ordinarily the males sit by day against the trunks of the trees with wings folded flat over the back, or they rest on a stem or twig with the wings bent forward against the sides of the body and the support (fig. 15).

The moths of both sexes of the fall cankerworm, as those of the spring canker, take no food, the mouth parts and most of the alimentary canal being rudimentary. The posterior part of the intestine, however, acts as a reservoir for the products of the excretory Malpighian tubules and becomes filled with a semiliquid, orange-red mass. In the female the eggs completely fill the body cavity, occupying all available space clear up to the front of the thorax. They are packed in jumbled masses in eight long, thin-walled sacs, which are the distended ovarian tubules.

The moths are never very active out of doors, but they show more animation on warm nights than they do on cold nights. When kept in cages in a room they remain quiet all day, but with the approach of evening, though the room be brightly illuminated with electric light, the males begin to flutter restlessly about, and the females are soon running briskly in all directions. Somehow they know when night comes, regardless of artificial conditions of light and temperature, once more demonstrating they they are not slaves of external conditions.

By a few simple expedients a female cankerworm moth can be made to give some interesting demonstrations of certain temperamental traits she possesses. If one is placed on a table at night and an electric light is held within 2 feet of her but to one side, she shows at once that light has a very powerful attraction for her. She immediately runs rapidly toward it. If the light is moved about over the table the moth follows every motion of it, and can be made to describe circles and all kinds of intricate figures until the experimenter tires of the sport.

This idiosyncrasy of the moth for going toward the light is an example of what biologists call *tropisms*. A tropism (from the Greek *trepein*, to turn) is an innate quality in an animal that makes it react in one way or another to external stimuli, without its "will" having anything to do with its actions. Tropisms may be either *positive* or *negative* according as the animal turns toward or away from the source of the stimulus. Plants also have tropisms, as for example, the well known habit of the sunflower for turning its face toward the sun. The property of being stimulated to movement by light is designated *phototropism*.

Another experiment with our moth will show that she possesses an impulse to go upward. Place an active individual on the side of a vertical block of wood and she immediately starts to ascend it. Turn the block end for end, she reverses and starts upward once more, and again the experimenter may amuse or instruct himself indefinitely or until he wearies of reversing the block. Any creature possessed of this innate impulse to go upward is said by the savants of tropisms to be endowed with *negative geotropism*, signifying that something impels it to go away from the earth.

Besides phototropism and geotropism there are many other tropisms; that is, if tropism is anything more than a theory, or a name for something we do not understand. Reaction to heat is *thermotropism*; reaction to water is *hydrotropism*; reaction to chemical substances is *chemotropism*, the last ordinarily called smell or taste in animals with conscious perceptions. But all tropisms in animals are supposed to act in a purely mechanical way by affecting the muscles of locomotion or those by which the movements of the creature are directed. Thus, in the case of phototropism, if the light is coming at an angle, it strikes on one eye stronger than on the other, and if the animal is endowed at the time with positive phototropism, the reflex nerve current generated by the light on the optic nerve stimulates the muscles most strongly on the side of the body with the eye that receives the most light. These muscles contract, the body bends toward the light until both eyes receive the same stimulus. The creature must inevitably go toward the source of the light. If it is a flying moth it beats itself against the globe or burns itself in the flame, unless it possesses a strong negative thermotropism; then the heat repels it and it flies in circles about the light.

The mechanical idea of tropism was first invented to explain the movements of certain plants, and was later extended to animals to account for the definite responses to specific stimuli by such animals as could not be supposed to receive conscious sense impressions or to have the power of voluntary action. Now there is a tendency to explain the acts of all animals as tropisms. A study of the behavior of animals under different conditions, however, necessitates a modification of the extreme mechanistic conception of tropisms as applied to animals. Night-flying moths, for example, are attracted by artificial lights but are nocturnal in their habits; they are positively phototropic only up to a certain degree of intensity of light. We have noted, also, that the nocturnal cankerworm moths become active in a cage as evening approaches, regardless of artificial illumination about them. They appear, therefore, to have regularly recurring periods of activity which are not influenced by local external conditions. Periodic activity of this sort is known as physiological *rhythm*. Many insects and other animals are endowed with it.

The persistent going upward of the cankerworm moth might appear to the observer to be due to her center of gravity being behind the bases of her legs, which, by a natural equilibrium on a vertical surface, would swing her head upward and induce her to go in this direction as the one easiest to follow. But let her ascend to the top of the block and see what she does there. She very simply goes around the edge of the top surface and then proceeds down on the other side. The descent is made partly in a position with the head down and the abdomen straight up, and partly in a sidewise attitude with the body sustained horizontally. Clearly, then, the moth is not guided in climbing by any mechanical adjustment of her weight with regard to gravity.

A child watching a canker moth go up the block, encircle the top, and then go down again would say the moth found no way of going higher and so did the natural thing in going down again. The biologist, however, who has invoked a tropism to get the moth up to the top of the block, must invoke another to get her down. He, therefore, says that under the altered conditions the insect has become negatively geotropic, without explaining very definitely just what has happened to its positive geotropism, which will subsequently encounters a vertical surface.

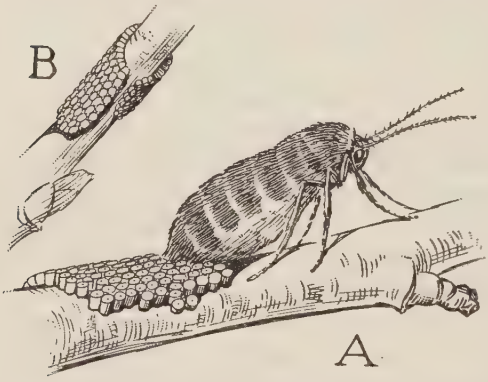


FIG. 16.—Female moth of fall cankerworm and eggs. A, moth depositing flat mass of eggs on a twig; B, egg mass nearly surrounding a twig

In this connection it is interesting to note that when the moth is on a vertical surface the light does not attract her. She persists in going up or down regardless of where the electric bulb may be held, though on the horizontal surface she once more follows its lead. Either, then, her geotropism is stronger than her phototropism, or the condition of being on a vertical surface somehow inhibits her response to light.

The writer is not particularly recommending the theory of tropisms as applied to animals. The evidence in favor of it has been presented too exclusively by its devotees, the work of skeptics would be more convincing. But a careful study of all the facts bearing on the habits and behavior of insects, and the physical and physiological conditions that modify them, is very much to be desired, regardless of what conception we may have of the inner workings of

the insect organism. A study of insect "psychology" is likely to open many new lines of attack in our efforts to control the ravages of injurious species.

When the female fall cankerworm moth is ready to deposit her eggs, she selects a site most anywhere on the limbs or twigs of the tree she has ascended. The eggs are stuck to the surface of the bark (fig. 16, A), not tucked away in cracks or crevices as are those of the spring cankerworm. When placed on a large limb they are spread out in a flat mass, but on smaller branches the mass is curved to fit the contour, and on the twigs it may almost completely encircle the support

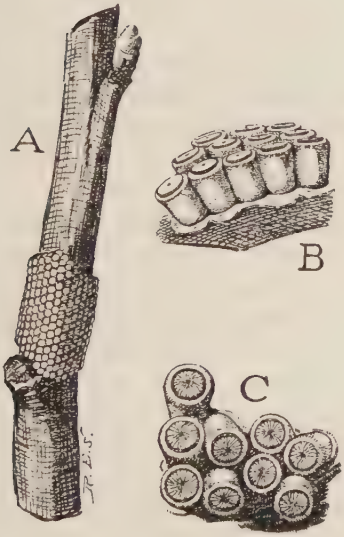


FIG. 17.—Eggs of the fall cankerworm. A, egg mass on a twig; B, group of eggs, side view; C, group of eggs seen from above

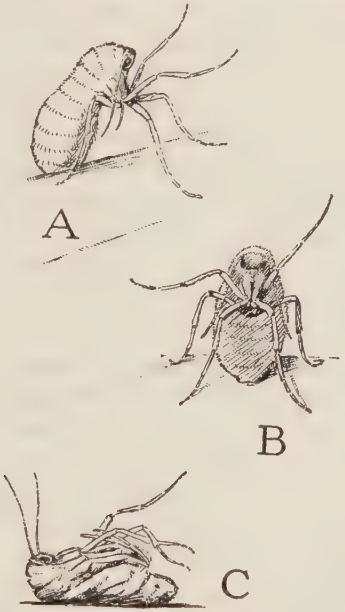


FIG. 18.—Female fall cankerworm moths exhausted after egg laying. A, B, moths still sitting on twig; C, moth lying helpless on her back after falling from the twig

like a cylindrical jacket (fig. 16, B). Each egg looks like a miniature earthenware jar (fig. 17, B, C), grayish in color, flat on top, rounded at the bottom. The eggs all stand close together, fastened to the bark by a gluey substance which the female discharges from glands connected with the opening of her egg duct. The eggs are often so evenly placed that their tops form regular rows in three directions across the surface of the mass. Usually there are between 200 and 300 eggs in each mass, but there may be as many as 400.

After disposing of her eggs, the female in most cases is shrunken and exhausted. Of two moths that deposited the last of their eggs in captivity on November 9 and 10, respectively, one sat beside them

on the twig for a day and a half, the other for two whole days. Most of the time each maintained the curious attitude shown at A and B of Figure 18, the body being propped up almost vertical on the front and hind pairs of legs, while the two middle legs were slowly waved in the air. Finally the moths became so weak that the legs failed to maintain the grasp on the twig, and each in turn dropped to the surface of the table below, landing legs upward, and remained helplessly in this position. But life was not yet extinct. The female that deposited her eggs on the ninth lay for three full days slowly moving one leg (fig. 18, C); the other showed similar but decreasing signs of life, until finally there was but a feeble trembling of one foot. Both died on the 14th, five and four days, respectively, after egg laying.

On the other hand, active and plump-looking females are sometimes taken out of doors, which, when killed and dissected, are found to be completely devoid of eggs. These eggless females almost always have a large bubble of gas in the thorax, contained in a sack-like pouch of the œsophagus. Specimens with eggs were never found to contain this air bubble. All of the females, however, undoubtedly soon perish; and the males must encounter a similar fate.

The lives of these creatures seem to us to be but periods of miserable existence, activated by an incomprehensible devotion to a physical duty. Yet, there is no reason to believe that they suffer; they are simply differently constituted in some way from the majority of insects. Their lives are as normal as are those of the warmth-loving moths that flock to our lights on hot summer evenings, or of the seemingly care-free butterflies that frequent our gardens on sunny afternoons, where they meet their affinities or refresh themselves from the nectar of the flowers.

The eggs of the fall cankerworm remain on the trees all winter to hatch next spring about the first of May, or about the time the new leaves are unfolding. When nature gives the signal, the caterpillar within the egg gnaws an irregular hole in the top of its cell large enough to permit its head to emerge (fig. 19). Then a long, slim body suddenly shoots out, pulls itself free from its prison, and the young cankerworm loops away in search of its first meal.

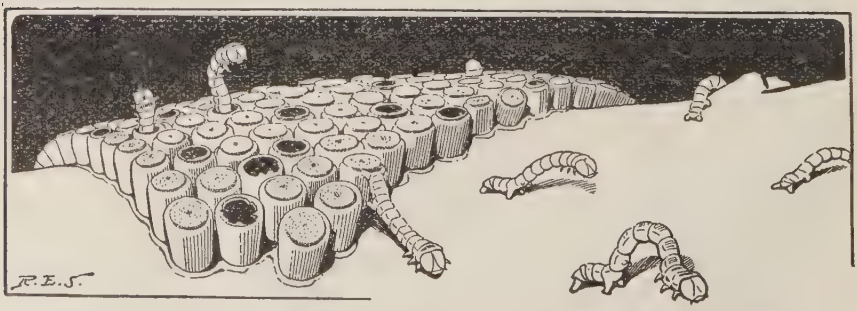


FIG. 19.—Young fall cankerworms emerging from the eggs (greatly enlarged)

A BOTANICAL TRIP TO ECUADOR, PERU, AND BOLIVIA

By A. S. Hitchcock

[With 15 plates]

In order to obtain direct information concerning the grasses of the central Andes region a trip was made in 1923 to Ecuador, Peru, and Bolivia, leaving Washington in May and returning in February. The work was primarily for the Department of Agriculture but that done in Ecuador was in cooperation with the Gray Herbarium of Harvard University and the New York Botanical Garden.

ITINERARY IN ECUADOR

Arriving at Guayaquil June 16, several days were spent in establishing connections. Dr. F. W. Goding, our efficient consul general at this city, was very helpful throughout my stay in Ecuador. Through the courtesy of Mr. Orr, geologist, and Mr. Clark, manager, five days were spent at a camp between Guayaquil and Salinas where a well was being sunk in search for petroleum. After collecting a few days in the vicinity of Guayaquil, headquarters were removed to Huigra on the railroad to Quito at an altitude of 4,000 feet. Three excursions were made from Huigra to the coastal plain. The first was to Ingenio Valdez, near Milago, a sugar plantation and factory, of which Sr. S. Perez Conto is manager. Mr. Meigs, superintendent, and Mr. Platts, chemist, are Americans. Mr. Pachano, an Ecuadorian botanist, aided greatly here in the collecting of material. The second visit was to Teresita, a plantation owned by Mr. J. A. Cleveland, an American long resident in Ecuador. This plantation lies in a very wet belt at the foot of the mountains. The third visit was to the Panigón plantation, 8 miles south of Milago. The manager of this plantation is Mr. James Rorer, the well-known mycologist, formerly of the United States Department of Agriculture and of Trinidad, West Indies.

After collecting several days at Huigra, headquarters were transferred to Quito July 31. August 5 to August 15 were occupied by an overland trip to Tulcán at the Colombian border, accompanied by Mr. J. R. McWilliam, of Quito, who was friend, guide, and interpreter. The route lay through La Providencia, Otavalo, Ibarra,

La Rinconada, and the return about the same way, passing through Malchinguí and Pomasqui. La Rinconada is a large ranch, whose owner, Señor Tomayo, courteously entertained us. After our return to Quito a visit was made to Pichincha, a volcanic cone 15,000 feet high a few miles from the city. The next overland trip was made in company with Mr. McWilliam through southern Ecuador, August 25 to September 13. Going from Guayaquil to Santa Rosa by boat we took horses for the remainder of the way. The first stage, two days, brought us to Portovelo, a gold mine in charge of Americans. The manager, Mr. Tweedy, whom I met in Quito, and Mr. Kellogg, the superintendent, entertained us here, and the American conditions, including food, were surely a pleasant break in the primitive life we had been living. The second stage, three days, brought us to Loja by way of El Tambo and La Toma. The third stage, four days' travel and one day's rest, brought us to Cuenca, the third city in Ecuador. The route lay through San Lucas, Oña, and Nabón. The fourth and last stage, two days, took us to Huigra on the railroad.

In September Mr. McWilliam and I journeyed into the Oriente a short distance, starting from Ambato. At the end of the first day we reached Baños and the second day Cashurco. We returned to Ambato at the end of the fourth day. On October 4 an ascent of Chimborazo was made to snow line at about 16,000 feet, starting from Urbina on the Guayaquil and Quito railroad (11,841 feet). This ended the field work in Ecuador.

TOPOGRAPHY AND CLIMATE OF ECUADOR

Ecuador has three well-marked regions—the coastal plain, between the Pacific Ocean and the Andes, the mountains with their interior valleys, and the vast forested region to the east of the mountains, the Oriente.

The coastal plain is about 100 miles wide, and gradually rises to the base of the mountains where the elevation is about 1,000 feet (at Bucay on the railroad). The rainfall is heavy in the Colombian coast region and in northern Ecuador but decreases rapidly southward and one soon arrives at desert conditions in northern Peru. The temperature of the tropical west coast of South America south of the equator is much modified by the cool Humboldt current coming up along the coast from the Antarctic regions. The coastal cities are not as warm as the latitude would indicate. The average temperature for Guayaquil is 27° (80° F.) for the year, 28½° (83° F.) in January and 25½° (78° F.) in July. The maximum of 35° (95° F.) and the minimum of 19° (66° F.) are very rarely attained. The daily variation of temperatures is usually less

than 15° F. The rainfall by months in inches (United States Weather Bureau) is as follows:

	Inches		Inches		Inches
January	9.92	June	0.75	November	0.27
February	9.75	July	.41	December	1.84
March	7.52	August	.00		
April	5.22	September	.11	Total	38.65
May	2.33	October	.43		

The mountainous portion of Ecuador, the Cordillera, consists of two main nearly parallel chains with high valleys or plateaus between. The interior valley is divided into depressions by cross ridges. The only railroad of importance runs from Guayaquil east to Bucay and there begins the ascent of a valley, climbing past Huigra and Alausí to the pass at about 10,000 feet, then descends into one of the valleys to Riobamba, then over another pass, at Urbina (nearly 12,000 feet) on the flank of Chimborazo, and into another valley with Ambato as its center. There is another pass in the vicinity of Cotopaxi, and one then descends into the valley of Quito, the northern terminus of the railroad. The valleys are 8,000 to 10,000 feet altitude. Further northward there are the valleys in which lie the cities of Ibarra and Tulcán. The climate in these valleys is temperate and equable. The altitude of Quito is about 9,500 feet, and the climate is more bleak than at Ambato at about 8,500 where it is very satisfactory. The average yearly temperature at Quito is about 12½° (54½° F.) but the daily variation may be as much as 18° (32° F.). The rainy season is from January to May, and the total average annual precipitation is 1,120 mm. (40 inches), but since the city lies between two regions of opposite rainfall periods (in the east Andes the rainy season is from March to November) there is some rain during the dry season. The average total for the five months of the rainy season, January to May, is 654 mm. (according to Hann, Handbuch der Klimatologie), and 463 mm. for the dry season, June to December.

There are about 20 snow-capped peaks in the Ecuadorean Cordillera, some of them being among the highest of the Andes. The three best known outside of the country are Chimborazo (about 20,500 feet), Cotopaxi (about 19,500), and Tunguragua (about 16,700 feet). These are majestic volcanic cones visible at a great distance.

The ladder-like structure of the Cordillera of Ecuador is shown by the following table. The route from Tulcán on the north to Loja on the south traverses eight major passes. The cities lie in the valleys between. The passes are at approximately the lowest point in the cross range. The heights in meters are taken from Wolf (Geografía y Geología del Ecuador), the equivalent being given as feet in paren-

thesis. The altitudes of the towns in feet are from the Commercial Travelers' Guide to Latin America (Dept. Commerce, Misc. Ser. 89).

	Meters	Feet		Meters	Feet
Tulcán	2,757	9,000	Riobamba	2,740	9,000
Pass	3,405	(11,170)	Pass (about)	3,000	10,000
Ibarra	2,225	7,500	Alausí	2,390	7,500
Pass	3,099	(10,167)	Pass	4,445	(14,582)
Quito	2,850	9,500	Cuenca	2,581	8,468
Pass	3,604	(11,824)	Pass	3,424	(11,233)
Latacunga	2,801	9,055	Oña	2,452	(8,044)
Ambato	2,608	8,500	Pass	3,259	(10,692)
Pass	3,607	(11,833)	Loja	2,220	7,360

The highland of the Andes is usually known as the sierra. The forested slopes of the eastern side are called the montaña. The high, treeless regions below snow line are called páramos, the same name being used in Colombia.

The Oriente is the region lying east of the Cordillera in the valley of the Amazon. It gradually merges into the montaña of the east slope and is only partially explored. The inhabitants are mostly indios or aboriginal tribes, though there are a few settlements of half-casts and negroes along the rivers, with here and there a white man. The Oriente is in the main covered with virgin forest and travel is chiefly by canoe at the lower altitudes. In the western portion where the rivers are too precipitous for canoes the travel is by trail, but owing to the high rainfall, the absence of bridges, and the general defectiveness of the paths, the going is difficult. Much of the Oriente is disputed territory between Ecuador and Peru. On Peruvian maps the boundary line runs about 20 miles east of Loja, Ambato, and Ibarra.

CITIES AND RAILROADS IN ECUADOR

Aside from the disputed Oriente, Ecuador has an area of about 120,000 square miles, about the size of Arizona or New Mexico. The largest city, Guayaquil, has a population of about 100,000, and Quito, the capital and second city, a population of about half as much.

The most important railroad, the Guayaquil and Quito, goes across the coastal plain from Duran, opposite Guayaquil, and ascends a valley to the sierra, passing by Huigra and Alausí. The building of the road here was difficult and the scenery is correspondingly magnificent. In places there was not room for curves, so switchbacks or zigzags were resorted to. After rising over a pass at Palmyra a bleak wind-swept páramo of about 10,000 feet altitude, the road descends to the valley of Riobamba, which is the terminus for the first day's travel, as the trains do not run at night. The second day the train passes over the flank of Chimborazo, which great snow-

covered cone is a magnificent sight in clear weather, the road reaching an ultimate altitude at Urbina of nearly 12,000 feet, then on into the valley of Ambato and Latacunga, over another pass near the great peak of Cotopaxi, and finally descending to Quito, which lies in a sort of bowl. A few minor railroads lead inland a short distance from some of the coast towns. The commerce of the interior cities that are not served by the railroad is by means of pack trains over roads that are much used and rarely repaired.

PRODUCTS OF ECUADOR

The chief industry of Ecuador is agriculture. The mineral resources are great, but through lack of suitable facilities for transportation these resources have been only partially developed. There is a large gold mine at Portovelo, in southern Ecuador, where we had the privilege of staying a few days on our journey through this region. Copper and other metals are also found and petroleum is produced in the region west of Guayaquil.

The chief agricultural export product is cacao, from which chocolate is made. The industry has been threatened recently by a disease, witches'-broom, which has greatly reduced the output in certain regions.

Sugar raising is an important industry but the product is chiefly used within the country. Considerable coffee is exported, and formerly the ivory nuts and rubber were important products.

The making of Panama hats is the leading manufacturing industry, of which the export value for 1920 was $1,500,000. These are made from a palm growing on the coastal plain and are woven or plaited by hand. In some localities a large part of the population from children to the aged take part in the manufacture.

In the valleys of the interior the usual crops of temperate regions are raised, mostly for home consumption, such as wheat, barley, and alfalfa. Stock raising is increasing in importance.

COLLECTING PLANTS IN ECUADOR

As the work in Ecuador was of a cooperative nature as indicated in the first paragraph, the collecting included all kinds of flowering plants of which three sets were obtained. The collection included 2,137 numbers (19914 to 22050), a large part of which were obtained in triplicate. A sufficient amount of stock newspaper sheets cut to folders 11½ by 16½ inches, the so-called inner sheets, was taken from America for the entire trip as one can not depend upon getting such things in Ecuador. Also there were taken about 500 driers, and 200 sheets of corrugated paper faced on one side. Two kerosene cooking lamps with 4-inch wicks furnished the heat. Packages of

plants, placed over a stove and surrounded by a curtain of cloth to force the hot air through the packages, would dry in a few hours. The corrugated paper between the specimens allowed a free circulation of hot air.

When collections were made at towns along the railroad and one could do the drying at a hotel there was little difficulty in preparing specimens. In visiting outlying places and traveling overland certain modifications were necessary.

The usual method of travel overland is to hire horses or mules with driver for a definite stage, usually not to exceed two or three days. In addition one should have a guide and interpreter. In the present case I was fortunate in having the services of Mr. J. R. McWilliam, a young Seventh-day Adventist missionary of Quito, who spoke Spanish and was familiar with the country and its customs. Most of the natives—that is, the Indians—speak Quichua and often little or no Spanish. The mule driver, however, could act as an interpreter for Quichua. The outfit was reduced to simple terms and was carried on two pack animals.

It is essential to successful travel that one should preserve one's health. In the uplands there was no malaria but dysentery and other intestinal diseases were common. To avoid dysentery and typhoid one should drink no unboiled water and eat no uncooked vegetables. Fresh fruit should be inspected and peeled with care.

Since the travel was in a primitive country it was necessary to provide certain comforts in order not to be worn out with the continuous strain of horseback riding. I took with me from Washington a McClellan army saddle and a saddle blanket, also a folding army cot with pad or thin mattress, and blankets. In actual travel navy duffle sacks of heavy canvas were used to hold the baggage, one sack on each side of a mule. The cot and pad filled one sack. A supplementary supply of food was taken as one could not depend upon getting what one needed at small inns or tambos. Such supplies included condensed milk, sugar, tea, butter, sardines, canned salmon, canned fruit, and crackers. Sometimes it was necessary to stop at Indian huts. Bread could rarely be obtained except in the larger places. Milk, butter, and sugar were luxuries. Hot water could always be furnished and usually caldo, a kind of stew or soup with potato and scraps of other things—just what other things one could not know. Eggs could sometimes be obtained. Candles were a necessary part of the equipment as light is rarely furnished at small places. The towns are situated in fertile valleys and these, being highly cultivated, furnish little of value to the plant collector. The interesting plants were obtained in going over the passes. On the other hand the limiting factor determining the arrangements for each

day's journey was feed for the animals. The mules are not given grain but depend upon cut green feed. This is fed at night and morning, and when possible at noon. In the uplands the fodder is usually alfalfa. Other fodder given in certain localities where alfalfa was not available was green cornstalks, sugar cane, bamboo, cachi (*Axonopus scoparius*), and in one region in southern Ecuador, cakes of raw sugar. Because of the necessity of stopping overnight in the towns we were often hurried in our collecting on the passes. We could camp in the collecting areas but we could not provide feed for the animals—a prime consideration in traveling. In some places there was grass, but it was not practicable to allow the animals to roam over grassland at night. If they are not lost they have at least been unable to take proper rest and are likely to give out the next day.

Since we drank no unboiled water, we depended on large quantities of weak tea at our meals, supplemented occasionally by bottled water or "pop" at the larger towns. Travelers generally depend on bottled beer or other alcoholic drink which is widely distributed, being sold at the smallest roadside shop, but we were at a disadvantage as we did not drink beer.

It was fortunate that I took with me a cot. This I used even though there were a bed in the room. Insect pests were usually present in the smaller hotels or in the Indian huts where it was necessary to stop. The usual pests were fleas, bedbugs, and lice. In setting up the cot I was careful not to let it or any of my belongings touch the walls. Furthermore, at Indian huts I would not have been allowed to stop if I could not furnish my own bed. Being a white man, the natives would not consent to have me share their simple belongings after their own manner.

ITINERARY IN PERU

Peru was entered at Callao, the port of Lima, which lies a few miles inland. Lima is a fine modern city. The climate here is fine, and, though in the Tropics at near sea level, the heat is never oppressive. The whole coast south of Ecuador is kept cool by the Humboldt Current coming up from the south. Two days were spent at Lima establishing connections for further work.

The first trip was to the interior over a wonderful mountain railroad to Oroya. The train leaves Lima about 7 a. m. and for three hours traverses the coastal plain. Then it starts to climb the great Cordillera through a most amazing series of gorges, crossing deep valleys and skirting precipices. At about 3 p. m. the summit of the pass (in a tunnel) is reached at nearly 16,000 feet (15,689 feet) and then descends to the town of Oroya at about 12,000 feet. Thus in five

hours one ascends from near sea level to nearly 16,000 feet, a great strain on the bodily organs, and many people are attacked by soroche or mountain sickness. The tunnel at the summit is 3,859 feet long and the place is surrounded by high snow-capped peaks and ridges rising 1,000 to 2,000 feet higher. The vegetation here appeared to go up to almost 17,000 feet. Some idea of the remarkable railroad may be obtained from the fact that on the road, including the branch to Huancayo, there are 65 tunnels, 10 of them being more than 500 feet in length, 21 switchbacks or zigzags, and 61 bridges. The scenery is indescribably grand.

Through the courtesy of the Cerro de Pasco Copper Co., I was able to stop at the company's hotel and also later at Cerro de Pasco. From Oroya I went by auto to Tarma and then to La Merced, descending to about 3,000 feet. The next morning I went on horseback to Colonia Perené, a large coffee plantation on the Perené River at about 2,000 feet altitude, in the Amazon Valley. I presented my letter of introduction from the Peruvian Corporation in Lima and was cordially entertained during my stay by the manager, Señor Valle-Riestre. On the plantation are 1,600,000 coffee trees.

On the return from the Perené Colony I went to Junín, on the road to Cerro de Pasco, where I was met by an agent of the Atocsaico Ranch who conducted me to the ranch about 12 miles to the west. Here I was kindly looked after by Mr. McKenzie, the manager of the ranch, to whom I had a letter from Señor Rizo-Patron.

Atocsaico is a sheep ranch at about 13,000 feet altitude, containing 11,000 acres. The sheep graze the year around and there is plenty of water. The equipment is modern and in good condition. The annual production of wool is about 60 tons. I was surprised to learn that one of the pests against which they are constantly fighting is the condor. I saw a huge pile of wings which represented dead condors for which a bonus had been paid. There are no trees on the ranch as the altitude is too great for their growth. The fuel is dried turf. It was interesting to note that they make their own lime from native limestone using sheep manure for fuel.

The next stopping place was Cerro de Pasco, a cold bleak mining town at an altitude of 14,300 feet. The road from Oroya to Cerro de Pasco lies over a great plateau or plain several miles wide at about 13,000 feet. Mr. Philpott, the superintendent, was very courteous to me and made arrangements for a visit to Goyllarisquisca. Fortunately, I was not at all affected by soroche or I should have been much inconvenienced by work at high altitudes. Mr. Philpott stated that 7 out of 10 people suffer when they first come but 75 per cent of these recover in a few days. Others must descend to lower altitudes at once or serious results may follow. The high altitude had a noticeable effect in that my lungs did not get sufficient air

while at rest and I would suddenly require a long breath. This became troublesome as I was going to sleep. My lungs accustomed to slow down would not supply sufficient oxygen and I would gasp for breath at the point of losing consciousness thus bringing me wide awake. This condition might continue for half an hour before I would finally go to sleep.

From Cerro de Pasco a trip was made on horseback to La Quinhua, 3,000 feet lower down a rocky valley, and another by rail to Goyllarisquisca. From near the latter place we descended on a cable car 5,000 feet to a coal mine. In this vicinity grasses were in good condition and a fine collection was made.

On returning to Lima I took a steamer for Mollendo, a port in southern Peru. In general the whole coast of Peru and northern Chile is a desert, rain coming at infrequent intervals. Sometimes one to several years, or even as much as 15 years, will pass between showers. At Mollendo the conditions are such that rains, though infrequent, come oftener than at other parts of the coast. At the time of my arrival the hills back of the town were green as a result of recent rains. I took advantage of these favorable circumstances to make a collection of the entire flora. The verdure extended for a narrow belt over only a few miles and back of this all was desert again.

From Mollendo I went by the Southern Railroad to Arequipa a fine city at 7,500 feet altitude. On the way we passed the curious crescent-shaped sand dunes that are moving across a desert plain. These are 10 to 15 feet high and about 100 feet across, all the same shape and about the same size, thousands of them, moving in the direction of the prevailing wind, high in the center and tapering out to the point of each crescent. The plain itself was of brown dirt but the dunes were nearly white, thus conspicuously set off.

As an example of the coincidences of personal contacts, I may record that I met here Mr. Delgado Vivanco, whose brother was a classmate of my son's at college and who extended to me at Arequipa many courtesies. Arequipa is beautifully situated. In the vicinity are three high snow-capped mountains, Chachani (20,000 feet), Misti (19,150 feet), and Pichu-Pichu (17,800 feet). Misti, close by, is a nearly perfect cone.

After leaving Arequipa I went to Juliaca, where the road branches, one division going to Cuzco, the other to La Paz. The trains run only by day and only twice a week. The first stage is Mollendo to Arequipa, the second from Arequipa to Juliaca, and the third from Juliaca to Cuzco on to La Paz. I had a letter of introduction to Colonel Stordy, director of the experiment station at Chuquibambilla on the road toward Cuzco. I remained at the station as his guest over one train. The ranch contains 18,000 acres and is

devoted mainly to sheep, of which they have about 15,000 head. The altitude is about 12,500 feet. The grazing here is fine.

The road to Cuzco continues over a great plateau 13,000 to 14,000 feet altitude, passing over a divide at 14,153 feet and descending to Cuzco at 11,000 feet. Cuzco is one of the old Inca cities and shows much evidence of Inca architecture. The Spaniards destroyed a large part of the old city, but many of the foundation walls remain upon which modern structures have been built. One can discern at a glance the difference between the old and the new. The old Inca walls are much more substantial and better made as a rule. In the outskirts are the well-known ruins of extensive fortifications, which I examined with interest and of which I took several photographs. The old walls are remarkable for the great size of many of the stones, weighing many tons. The largest stone is said to weigh 361 tons, and some of them to measure 27 by 14 by 12 feet. The second remarkable feature of the walls is the perfect fitting of the stones which are set without mortar or cement.

Through the kindness of officials whom I met at Cuzco I was able to make a trip on a new railroad to Ollantaytambo and by horse about 12 miles further down the valley toward Santa Ana, the ultimate destination of the road.

At Ollantaytambo there are more Inca ruins. On top of a very steep hill are several fine walls. Also there are 6 large stones 13 by 7 by 6 feet. How were they brought up here? The stones for all the structures were brought from a quarry many miles away. The builders had no beasts of burden except the inefficient llama, and no iron for instruments.

TOPOGRAPHY AND CLIMATE OF PERU

In a general way the topography is similar to that of Ecuador. There is a coastal plain between the mountains and the Pacific Ocean; a mountain mass, the Cordillera, extending north and south; and to the east a forested slope in the Amazon Valley. These three regions are usually referred to as La Cuesta, the Sierra, and the Montaña.

The coastal plain (La Cuesta) is extremely dry and, with the plain of northern Chile, constitutes one of the great desert regions of the world. There are numerous rivers, however, fed by mountain snows, that find their way across the desert to the ocean. The valleys of these rivers are occupied by an agricultural population that utilizes to the full the water for irrigation. As there are no railroads running north and south to connect these centers of population, there is little communication between them. In most cases the area of cultivation is some distance from the coast and the towns are connected with a seaport by a short railroad. The outlet

in all these cases is by sea, the isolated communities being served by coastwise steamers.

The Cordillera is broader than in Ecuador and consists, through much of Peru, of two more or less distinct ranges. The valleys between are, in places, high broad plains or plateaus with an elevation of 12,000 to 14,000 feet. There are numerous lofty peaks, several more than 18,000 feet. The mountain region, especially the part above tree line, is called the Sierra. The high plains and ridges below snow line are called punas, puna corresponding to páramo in Ecuador and Colombia.

The forested slope to the east, the Montaña, runs off into a comparatively uninhabited region as in Ecuador. But the subtropical slopes and valleys in the foothills are highly cultivated.

The climate of Peru is so varied that no general statement of value can be given. The coastal plain is dry and comparatively cool though tropical. The Montaña is strictly tropical and for the most part has a high rainfall. The Sierra is temperate and on the high plateaus may be cold and bleak:

The temperatures and rainfall for three places will give a good idea of the climate in a general way.

Lima on the coastal plain near sea level. Yearly average temperature 19° (66° F.); average for August 15.9° (60° F.); average for February 23° (73° F.). The average annual rainfall is 46 mm. (1.8 inches) of which 26 mm. (1 inch) fall in August and September.

Arequipa, 7,500 feet altitude, on the Pacific slope of the Andes. Yearly average temperature 13.5° (56½° F.); average for June, the coldest month, 13.2° (55½° F.); average for October, the hottest month, 14° (57¼° F.). The average annual rainfall is 147 mm. (6 inches) of which 142 mm. fall in January, February, and March.

Cuzco, in the Sierra, at 11,000 feet altitude. Yearly average temperature 10° (50° F.); average for July, the coldest month, 7.7° (46° F.); average for November, the hottest month, 11.3° (52½° F.). The average annual rainfall is 980 mm. (39 inches).

In the Montaña of eastern Peru the rainfall rises to 100 inches.

CITIES AND RAILROADS OF PERU

Lima, the capital of Peru, is a fine city of about 225,000 inhabitants and has many modern buildings. Callao, its seaport, with about 50,000 inhabitants, is a few miles away, but the two cities are now nearly continuous. Arequipa has a population of 55,000 and Cuzco of 30,000.

Aside from the railroads connecting small seaports with the interior agricultural valleys of the coastal plain, there are two main lines in Peru. These have been mentioned in a preceding paragraph. The first goes from Callao to Oroya and on to Cerro de

Pasco, with a branch from Oroya to Huancayo. The other goes from Mollendo to Cuzco, with a branch from Juliaca to Lake Titicaca and on to La Paz.

Another road goes on from Cuzco to Goyllarisquisca and a new road is under construction from Cuzco down the Urubamba Valley to Santa Ana. Several of the rivers of eastern Peru, branches of the Amazon, are navigable. Iquitos in the northeast is the outlet for all this part of Peru. Iquitos though 2,300 miles from the mouth of the Amazon has an altitude of only 350 feet. There are regular steamship connections with Manaos and Pará in Brazil, at which latter place one can get steamers to the United States and Europe.

PRODUCTS OF PERU

Agriculture and mining are the two great industries. Among agricultural products sugar takes the lead and cotton is second. These crops are raised chiefly in the irrigated valleys of the coastal plain. In the Montaña of the east coffee is important, and in certain localities coca. There is also some cacao and rice. Formerly rubber was a very important product from the wild trees in eastern Peru, but of late years the cultivated product from the East Indies has replaced it.

In the temperate regions of the Sierra the products are corn, wheat, barley, alfalfa, potatoes, and beans (the broad bean of Europe). These crops are raised, under favorable conditions, up to about 12,000 feet.

The mineral products of Peru are numerous, with copper taking the lead and silver second. Petroleum is increasing in importance.

ITINERARY IN BOLIVIA

After leaving Cuzco I went to La Paz, the capital of Bolivia, by way of Juliaca and Lake Titicaca. The train leaves Cuzco in the morning and, changing at Juliaca, arrives at Guaquí on Lake Titicaca in the evening. Here passengers take a small but comfortable steamer, with cabins, and cross the lake during the night. Lake Titicaca is the largest lake in South America, having an area of about 3,200 square miles. It is 130 miles long and has a maximum depth of 892 feet. The altitude is about 12,500 feet. The shores are for the most part low rather than precipitous, and there are no high mountains in the immediate vicinity. In the morning passengers take the train for La Paz over a plateau which gradually rises to 13,500 feet at the rim of the valley in which lies the city. It is a strikingly beautiful sight which meets the eye as one looks for the first time over this rim to the city of La Paz spread out in the valley 1,500 feet below. The steep side of the valley is negotiated by a winding electric road.

Four trips were made in Bolivia, to Illimani, to the Yungas, to Cochabamba, and to the southern border.

Illimani is the most accessible high mountain in the vicinity of La Paz. It lies to the east at a distance of about 30 miles and is a dominating factor in the scenery. From my hotel window, which faced the east, I had a beautiful view of this majestic peak, which was perfectly framed between other mountains closer to the city. Especially striking was the view at sunset as the glistening white reflected from the great snow cap passed into pink and purple and finally to a pale blue. The mountain does not end in a cone like Chimborazo and Cotopaxi of Ecuador, but is a short ridge of about three peaks, the highest of which is said to be 21,204 feet. Another mountain, Sorata (also called Illampu) lies to the north of La Paz about 60 miles, but can be seen from the city only under certain favorable conditions. This peak is a little higher than Illimani, 21,490 feet. In company with Mr. Dagg I went by mule back and with pack animals to Illimani, ascending to the base of the great glacier at about 16,000 feet. It took two days to reach a ranch at the base of the peak, one day to make the ascent, and one day to return to La Paz. The face of the glacier is about 100 feet high and at intervals drops masses of ice, which roll down the slope for some distance.

The trip to the Yungas was made in company with Dr. Otto Buchtien, the well-known German botanist, who has lived many years in Bolivia and has collected widely in that country as well as in neighboring parts of Peru and Chile. He has written a flora of Bolivia and has a better knowledge of the flora of the country than any other botanist.

The Yungas is an indefinite region lying on the Amazon slope of the Cordillera Real or eastern chain of the Andes, and includes the valleys and slopes of the Montaña toward the Beni River. More specifically it includes the provinces of Nor-Yungas and Sur-Yungas. Through the courtesy of Sr. J. B. Aramayo, director general of the railroad now under construction from La Paz to the Yungas, we were given facilities for the trip, including transportation on the completed part of the road from La Paz to Pongo, and mules and driver into the valley. The railroad ascends out of the valley of La Paz and over the pass of the Cordillera at an altitude of about 15,300 feet to Pongo at about 12,000 feet. From here we took saddle mules and one pack mule for a seven days' trip through Nor- and Sur-Yungas. First there was one long descent of 7,000 feet, then much up and down as rivers were crossed and ridges ascended. We passed through San Felipe and La Florida, ending the eastern journey at Chulumani, the capital of Sur-Yungas. The route then lay through Coripata and Coroico, the capital of Nor-Yungas, and

back by way of Bella Vista to Pongo. I was impressed with the endurance of the mules, which had nothing but the usual supply of green fodder yet showed no signs of exhaustion though traveling every day and put to severe tests in the constant ascents and descents of thousands of feet. Meantime I was collecting grasses as we traveled, this requiring dismounting many times a day as specimens were observed by the wayside.

The Yungas is a great center for the cultivation of the coca shrub, from the leaves of which the drug cocaine is obtained. The leaves are used almost universally by the Indians of the Sierra. The dried leaves are rolled up with a pellet of paste made from ashes and chewed to get the stimulating effect of the alkaloid released by the alkali of the ashes.

The third trip, to Cochabamba, was easily made by rail. I was greatly aided here through the cooperation of Mr. J. E. Washburn, who has charge of the American Institute, an educational institution. Cochabamba, at an altitude of 8,500 feet has a very salubrious climate and is a delightful place to live. It is the center of an important agricultural district.

The last Bolivian trip which was to the southern boundary, was made possible through the kindness of Mr. G. G. Trueheart, assistant general manager of the Ulen Contracting Corporation at La Paz. By rail I went to Atocha, the present terminus of the railroad under construction from Uyuni to La Quiaca in Argentina. The Ulen company furnished transportation from Atocha to Villazon and return, including construction trains for a short distance at each end and mules and driver for the hiatus between. This trip took about 10 days. Ultimately this road will be the main line from Buenos Aires to La Paz. La Quiaca, in Argentina, opposite Villazon in Bolivia, was visited to utilize the better hotel facilities. The whole of southern Bolivia is a desert, with many species of cactuses and other xerophilous vegetation. The agriculture is confined to the irrigated valleys.

After returning to Uyuni, the departure from Bolivia was made by way of Antofagasta, Chile, where I took a Grace Line steamer for Panama and a Panama Railroad steamer for New York.

The southwestern part of Bolivia becomes increasingly arid and there are large areas of alkali soil devoid of vegetation. In this region there is much borax taken out.

My work in Bolivia was greatly facilitated by Mr. Joseph Flack, secretary of our legation at La Paz, who, in the absence of the minister, put me in touch with officials and others who were very helpful in forwarding my work. Before leaving La Paz I had the pleasure of meeting our genial minister to Bolivia, Hon. Jesse S. Cottrell.

TOPOGRAPHY AND CLIMATE OF BOLIVIA

The high plateau of southern Peru between the western chain of the Andes which southward is the boundary between Bolivia and Chile, and the eastern chain, or Cordillera Real, broadens out in Bolivia to form a great central high plain about 500 miles long and with an average altitude of about 12,000 feet. East of the plateau there is a lower plain about 500 miles wide extending to the Paraguay river, sloping from 1,000 feet to nearly zero.

The climate corresponds to the altitude. The wet season is from December to May, and the months from November to January are called summer.

At La Paz (12,000 feet) the average annual temperature is 9.4° (49.° F), the average for June 6.7° (44°F.), and for November 11.5° (53° F.). The average annual rainfall is 538 mm. (22 inches) of which 322 mm. fall in the summer months December to February.

At Cochabamba (8,500 feet) the average annual temperature is 17.3° (63° F.), the average for June 14° (57° F.), for November 20° (68° F.). The rainfall is 462 mm. (18 inches), 208 mm. of which come in December and January.

CITIES AND RAILROADS OF BOLIVIA

La Paz, the capital, has a population of 107,000, while Cochabamba, Oruro, Potosí, Sucre, and Santa Cruz have a population of about 30,000 each.

The main line of railroad goes from La Paz to Uyuni in the south, where it connects with the Chilean Railroad to Antofasgasta. When the portion between Uyuni and La Quiaca, Argentina, is finished there will be through service from La Paz to Buenos Aires. Trains now run to Atocha. The distance between Atocha and La Quiaca is about 125 miles, a part of which is now covered by completed railroad, but not yet available for traffic. From this main line there is a branch to Cochabamba and another to Postosí. Sucre is the official capital of Bolivia, but the seat of government is in La Paz. Sucre is connected with Postosí by automobile service during the dry season, the time being about 10 hours. La Paz is connected with Mollendo, Peru, by rail, as previously noted. A third line to the coast is from La Paz to Arica in northern Chile.

PRODUCTS OF BOLIVIA

The chief products of Bolivia are minerals, of which tin, copper, and silver take the lead, although several others are important.

The agricultural products include those that have been mentioned for Peru, but none are exported in important amounts.

THE LLAMA

The llama is a curious animal that always attracts the attention of visitors. It is native to the uplands of the central Andes and was domesticated by the early inhabitants and is still used by the Indians extensively as a beast of burden. The long erect neck and graceful carriage give the animal a very stately appearance. As a carrier its efficiency is low as its load can not usually be more than about 75 pounds and it can not go more than 10 or 15 miles a day. For these reasons the white man has little use for it, preferring mules or burros. The reason for its slow speed is the fact that it is a cud-chewing animal and, needing the night for rest, it feeds during the day as it travels. No forage or grain is given, but it depends on the native grasses. The llama fits in very well with the agricultural economy of the natives. They cost nothing to support, as they graze at large and the Indian has plenty of time. They can not be used for riding animals, and when in use they are allowed to travel in droves freely without halters or ropes. They are rarely brought down to altitudes lower than 4,000 feet, and are at home particularly in the central plateaus of Bolivia and Peru, the range extending into southern Ecuador. Allied to the llama is a smaller animal, the alpaca, used for flesh and wool but not for bearing burdens. The vicuña, still smaller, is a graceful little thing like a small deer but allied to the alpaca. This animal is becoming rare and is under government protection to prevent its extermination by the Indians who use it for food.

BOTANICAL RESULTS

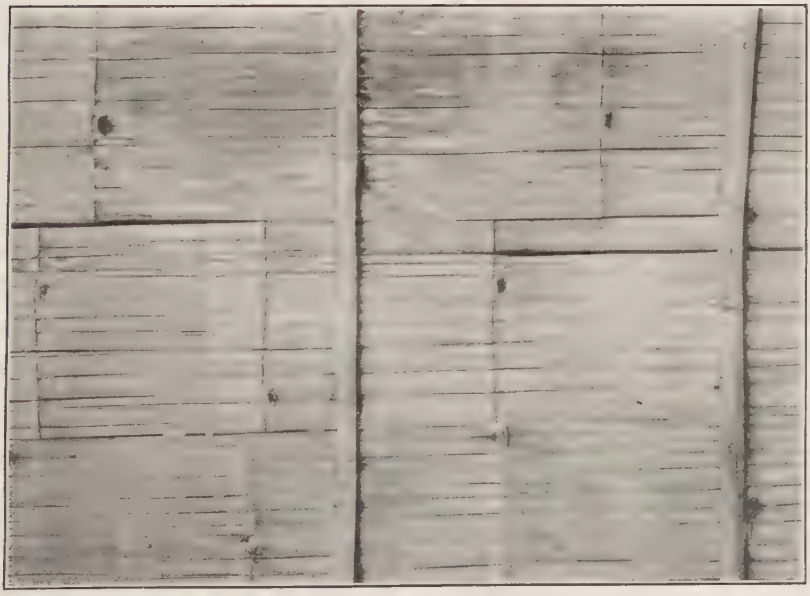
The botanical results of the trip to the central Andes are of importance. A large collection of grasses was made, which will be the basis of an account of the grasses of the three countries visited. Comparatively few botanists have traveled in this region. Among the early travelers may be mentioned Humboldt and Bonpland, who came from the north down through Ecuador to northern Peru, and Haenke, of the Malaspina expedition, who collected in central Peru. The Wilkes expedition stopped at Lima, but their collection of grasses was unimportant. Spruce, the English naturalist who spent several years in the Amazon Valley, came into Ecuador, and Jameson, an Englishman resident in Ecuador, sent many grasses to England. The late Prof. Luis Sodiro, of Quito, sent many plants to Europe and described some himself. Padre Luis Mille, of Quito, now has the care of Sodiro's herbarium. Father Mille very kindly allowed me to examine this herbarium, which contains the types of species described by Sodiro. Father

Mille is continuing the work of Sodiro in the study of the Ecuadorian flora.

Our knowledge of the flora of Peru has been greatly enlarged by the work of Dr. A. Weberbauer, a German botanist long resident in Peru and now living in Lima. Doctor Weberbauer is known not only by the large number of plants he has collected and sent to European herbaria but also by his great work on the distribution of plants in the Peruvian Andes (Die Pflanzenwelt der peruanischen Anden) and his phytogeographical map of the region (Mapa Fitogeographico de los Andes Peruanos).

Dr. Otto Buchtien's work in Bolivia has been mentioned in a preceding paragraph. Dr. H. H. Rusby, of Columbia University, New York, has collected in the montaña of northern Bolivia, and Mr. Macbride and his assistants are now engaged in botanical exploration in Peru for the Field Museum of Chicago. There have been other botanical explorers in the three countries under consideration, but altogether the flora is less known than most other parts of South America.

1. A PART OF THE TOWN OF HUIGRA, ECUADOR, ALTITUDE 4,000 FEET. MOST OF THE HOUSES ARE MADE OF BAMBOO BOARDS. BAMBOO STEMS ARE SLIT CLOSELY ON ALL SIDES AND FINALLY SPLIT DOWN ONE SIDE AND FLATTENED OUT TO FORM A BOARD. THIS IS A COMMON BUILDING MATERIAL IN THE COASTAL PLAIN



2. A CLOSE VIEW OF BAMBOO BOARDS

1. A NATIVE PLOW, CONSISTING OF A HEAVY POINTED STICK THAT IS DRAWN FORWARD THROUGH THE SOIL. NEAR LOJA, ECUADOR

2. THE MAIN ROAD BETWEEN QUITO AND TULCÁN. MUCH ERODED FROM HEAVY TRAFFIC WITH PACK ANIMALS AND NEVER REPAIRED

1. THE HEADQUARTERS OF THE ATOCSAICO RANCH, NEAR JUNÍN, PERU, DEVOTED TO SHEEP RAISING. ON A HIGH PLAIN, ABOVE TREE LIMIT, ABOUT 13,000 FEET ALTITUDE

2. A DROVE OF LLAMAS NEAR CERRO DE PASCO, PERU. THIS IS THE CARRYING ANIMAL OF THE INDIANS. THEY GO IN DROVES, FREE, GRAZING AS THEY GO, TRAVELING ABOUT 10 MILES A DAY, EACH CARRYING ABOUT 75 POUNDS

1. A Portion of Inca Ruins Near Cuzco. These Walls of an Ancient Fortress Are in Good State of Preservation. Some of the Stones Are Very Large, Weighing Many Tons

2. A Closer View of a Wall Showing the Perfection of the Workmanship. No Mortar Was Used, Yet the Stones Fit Accurately

1. EXPERIMENT STATION, CHUQUIBAMBILLA, NORTH OF JULIACA, ALTITUDE 13,000 FEET. HERE IS A NEARLY LEVEL PLATEAU OVER WHICH ONE RIDES FOR HOURS GOING FROM LAKE TITICACA TO CUZCO

2. A WOOLLY CACTUS (OPUNTIA FLOCCOSA) ON THE PLATEAU AT CHUQUIBAMBILLA, ALTITUDE ABOUT 13,000 FEET

1. SHEEP GRAZING AT 13,000 FEET ALTITUDE, CHUQUIBAMBILLA. THE BUNCH GRASS IS ICHU

2. A PEASANT'S HUT BUILT OF SOD, THE THATCHED ROOF (ICHU GRASS) ROPED DOWN. THERE IS A SMALL DOOR, BUT NO WINDOWS. CHUQUIBAMBILLA

1. INCA RUINS AT OLLANTAYTAMBO, PERU. THE STONES ARE ACCURATELY FITTED AS AT CUZCO (SEE PLATE 4)

2. AN OLD INCA ROAD, CUZCO, LEADING UP TO THE FORTRESS (SEE PLATE 4)

1. HOTEL AT OLLANTAYTAMBO. LLAMAS IN THE PLAZA OF THE VILLAGE

2. VICUÑA, A SMALL ANIMAL ALLIED TO THE LLAMA. THE INDIAN WOMAN IS SAID TO BE OVER 100 YEARS OLD

1. YARETA, MUCH USED FOR FUEL. SIERRA OF PERU. A TUSSOCK PLANT (AZORELLA MONANTHOS) GROWING NEAR SNOW LINE

2. BRUSH AND ROOTS USED FOR FUEL. ABOVE TREE LINE COAL AND WOOD ARE EXPENSIVE. BRUSH, ROOTS, AND YARETA ARE USED

1. A Coca Plantation in the Yungas, Bolivia. The Shrubs Are in Rows in the Terraced Ditches. Trees of Other Sorts Are Scattered Over the Slope. Coca Leaves Are Chewed with Ashes by the Indians as a Stimulant

2. A Glacier at 16,000 Feet on Mount Illimani, 30 Miles from La Paz

1. A HEAVY CART USED FOR HAULING ORE IN SOUTHERN BOLIVIA

2. A LIMEKILN NEAR UYUNI, BOLIVIA. THE LIME ROCK IS IN A LAYER AT THE SURFACE OF THE GROUND; THE FUEL CONSISTS OF FAGOTS OF A DESERT SHRUB NEAR BY

1. All Available Material Is Utilized for Buildings. A Hut at Uyuni Made in Part from Old Standard Oil Cans

2. A Desert Valley in Southern Bolivia. The River Bed Is Dry Most of the Year, but Is Occasionally Subject to Violent Flood, Dangerous to Travelers Who Use the Road Over the Dry River Bed

1. CHIMBORAZO, THE HIGHEST MOUNTAIN IN ECUADOR, ALTITUDE ABOUT 20,500 FEET

2. PARTIALLY WOVEN PANAMA HATS AT CUENCA, ECUADOR, ONE OF THE CENTERS OF THE HAT INDUSTRY

1. A MARKET WOMAN AT LA PAZ, BOLIVIA. THE STIFF WHITE HAT IS CHARACTERISTIC HERE

2. ALPACAS, ANIMALS ALLIED TO THE LLAMA, USED CHIEFLY FOR THE WOOL RATHER THAN FOR CARRYING BURDENS AS SHOWN HERE

1. REED BOAT USED BY THE INDIANS ON LAKE TITICACA. THE STEMS OF A NATIVE BULLRUSH ARE TIED IN SMALL BUNCHES AND THEN FASTENED TOGETHER TO FORM THE BOAT

2. A SMALL VALLEY NEAR OLLANTAYTAMBO, SHOWING TERRACES IN BACKGROUND. THE TREES ARE EUCALYPTUS

ORCHID COLLECTING IN CENTRAL AMERICA

By Paul C. Standley

[With 26 Plates]

INTRODUCTION

Central America is a paradise for the orchid hunter. According to a recent estimate there have been reported from the whole globe 15,000 species of these curious and fascinating plants, and nearly 1,000 have been recorded from a single Central American country, Costa Rica. From the other republics—Panama, Nicaragua, Salvador, Honduras, and Guatemala—about the same number of additional species have been listed, and Mexico is known to possess at least 500 more.

It has been the writer's privilege to spend two recent winters in Central America for the purpose of making botanical collections, and during this period particular attention has been devoted to orchids. Although many of the localities visited have been found deficient in these plants, others, and above all the mountains of Costa Rica, have furnished a rich harvest.

Central America was one of the first regions from which tropical orchids were introduced into the hothouses of Europe. Some of the more striking Mexican species had been described and figured in the celebrated *Thesaurus* published by Hernández in 1651, the first work treating of the natural history of tropical North America, but nothing was made known concerning the flora of Central America until a much later date. Probably the first botanical collector to visit Central America was Luis Née, a Frenchman by birth, botanist of the celebrated Spanish voyage around the world under the navigator Malaspina during the years 1789 to 1794. Née visited Panama, and is known to have collected plants upon Ancon Hill, the landmark of the Pacific end of the Canal. Several of the most common tropical American plants were first described from specimens obtained by him at this locality.

It was not until after the first quarter of the nineteenth century that any botanical work of importance was carried on in Central America, or any progress made toward a knowledge of the orchids.

George Ure Skinner, an Englishman who resided for many years in Guatemala, beginning in 1831, is said to have introduced into cultivation in England nearly 100 species of orchids, a large number for that day, when orchid culture in Europe was still in its infancy. The famous Danish collector and botanist, Oersted, was the first to visit (1846–1848) Costa Rica, where he collected some of the most beautiful of all our American orchids. An extended visit to many parts of Central America, including the rich regions of Guatemala, Costa Rica, and Veraguas, was begun in 1846 by Warscewicz, who traveled in search of orchids and hummingbirds, certainly a choice of interests in which he was to be envied. Warscewicz discovered many of the showy Central American representatives of this group. Other botanists who took an important part in the early exploration of Central America were Berthold Seemann, of the Herald expedition, who first made extensive collections in Panama; Tate in Nicaragua; Fendler (famous as the first to make a collection of any importance in the State of New Mexico) in Panama; Hoffmann and Wendland in Costa Rica; and Hayes and Wagner in Panama. In addition, Central America was visited by commercial collectors sent from Europe in search of orchids, palms, cacti, and other plants of horticultural value, and at times the export of living orchid plants to Europe by native collectors was a thriving industry. Thus, many dozens of persons whose names have not been preserved aided in accumulating our present knowledge of the orchid flora.

It is during the past thirty years, however, that the most important botanical work has been carried on in Central America. In Costa Rica large collections of orchids have been made by Tonduz, Pittier, Werckle, Brenes, Jiménez, the Brade brothers, and others. The orchid flora of Panama has been well explored by Powell, and in Guatemala extensive collections have been made by von Tuerckheim, especially in Verapaz. Several collectors from the United States have visited Central America, and have accumulated large quantities of plants, although few have devoted special attention to orchids. During the past fifteen years hundreds of new species of Central American orchids have been described, mostly from Panama, Costa Rica, and Guatemala. These three Republics and Salvador are those whose floras are best known. Of Honduras and Nicaragua, both of which doubtless will furnish a large number of orchid species, we still know very little, for scant exploration has been conducted there, owing largely to difficulties of transportation.

In view of the great amount of botanical exploration that has been carried on in Central America it might be questioned whether it is necessary to make further visits to a region of such comparatively small area. There is no doubt, however, that our knowledge of the

Central American flora is still very imperfect, and that many years more of intensive exploration are necessary. At present it is possible to obtain new plants even in the localities most often visited, and it frequently results that conspicuous and important plants, well known locally, are unknown to science. In the case of orchids, because of their peculiar distribution and mode of growth, the need for additional exploration is greater than in the case of most other groups of plants, and it is certain that the number of orchids known to exist in Central America will be greatly increased, perhaps even doubled, in future years.

ORCHIDS OF NORTHERN CENTRAL AMERICA

The portion of Central America with which the writer is most familiar, aside from the Canal Zone, is the Republic of Salvador, where five months were spent in 1921–22. Salvador unfortunately has few orchids, and only about 50 species are known there, most of these having been collected by Dr. Salvador Calderón and the writer. Salvador undoubtedly has a smaller orchid flora than any other Central American country, because its climate is comparatively dry and the country lies wholly upon the Pacific slope, the Atlantic slope being richer in these plants. Future exploration in small areas of forest remaining upon the higher volcanoes will doubtless reveal a good many additions to the list now known.

Of the Salvadorean orchids the handsomest is *Cattleya skinneri*, widely distributed in Central America, a showy species (pl. 20), known here as *San Sebastián*. During the dry season, when the trees upon which they grow are nearly or quite devoid of leaves, the huge plants covered with flowers are conspicuous masses of color. Bunches of the flowers are brought frequently to the markets for sale. Some fine plants of another striking orchid, *Epidendrum aurantiacum*, notable for its clusters of orange blossoms, were seen in the mountains about Ahuachapán. In the same mountain range vanilla grows in some abundance, and doubtless occurs in other regions as well.

In late spring of 1922 several weeks were spent upon the north coast of Guatemala, near the famous Maya city of Quiriguá. This area belongs to the wet coastal belt, and has an altitude of only a few hundred feet above sea level. Because of this slight elevation, comparatively few orchids occur here, and at this season of the year still fewer were in flower. Still, here and there upon the trees, especially in deep swamps, which are filled with giant trees and tangled thickets of native bamboo, there were found a few orchids worth collecting, certainly more than it would be possible to find in any single locality in Salvador.

Next to Costa Rica, Guatemala is the Central American country which has yielded most orchids, about 340 species being reported. Of all the Central American States, Guatemala has the greatest diversity of topography, elevation, and climate, and consequently the most varied flora, although the actual number of species may not be so high as in Costa Rica. For orchids, the most productive portions are the humid valleys of the departments of Alta and Baja Verapaz. Many of the mountain ranges have a temperate climate, too cold for the best development of these plants, and there are many miles of pine forest, where few orchids may be expected. There are also wide cactus deserts, closely resembling those of northern Mexico, where very few orchids grow.

Guatemala counts among its orchid species many that are noted for their beauty. Most remarkable is a *Cattleya* (*C. aurantiaca*) with orange-red flowers, which grows upon rocks and bald-cypress trees (*Taxodium mucronatum*) at high altitudes.

Of the orchids of Honduras and Nicaragua, as already stated, little is known. From Nicaragua 65 species have been reported, and from Honduras about the same number. Both countries have mountain ranges and humid forests, in which many orchids must await the discoverer. The scant information available concerning the Nicaraguan flora reveals so many plants of exceptional interest, that it is certain the country will later yield many other things equally remarkable. The most inviting and tantalizing view, botanically, that I have ever seen in Central America is that obtained in Salvador of the blue mountain wall that lies to the north along the Honduran frontier, near at hand yet almost inaccessible. Nothing is known of its flora, but it must harbor a host of strange plants. Along the Atlantic coast of Honduras a large collection of orchids was made recently by Mr. Oakes Ames, but no account of it has yet been published.

ORCHID COLLECTING IN PANAMA

In Panama the writer is acquainted only with the Canal Zone and its immediate vicinity, a region typical of the lowland or *tierra caliente* of both the Atlantic and Pacific coasts of Central America. Although only 40 miles in breadth, the Isthmus at its narrowest point exhibits an unexpected diversity of physical and floral characters, because there is a strongly marked difference between the climates of the two coasts. It is thus possible to study in the closest proximity areas of vegetation typical of the humid Atlantic coast and of the comparatively arid Pacific littoral, the latter with its well-defined wet and dry seasons.

In the Canal Zone the highest hills have an elevation of about 500 feet. Toward both the west and east in the Republic the hills

rise rapidly until high mountains are soon reached, but unfortunately none of these are easily accessible from the Zone. Near the Canal most of the land has been deforested and the original vegetation greatly modified, but even within the Zone there remain some areas of nearly or quite virgin forest, within which it is possible to study the primeval vegetation. In the dense and humid forests, composed of lofty trees with but scant undergrowth, careful search will disclose a fair number of orchids.

After the Canal had been completed and water was turned into the Gatun Lake Basin, as the water rose large stretches of forest were inundated and the trees soon died. Great expanses of the lake waters are still covered with protruding dead tree tops, which give a decidedly dreary and unattractive aspect to the landscape. After the trees died the epiphytic plants continued to grow, and were much more conspicuous than before. Among the dead branches there was an abundance of orchids, and it was easy to collect them from a boat. Practically all the orchid plants have now been removed, however, and little of interest is to be found in these areas.

The lowland forests of the Canal Zone are typical of many other regions throughout Central America. Such forests are not the most favorable localities in which to search for orchids, since these plants attain their best development at much higher altitudes. On the Atlantic slope the lack of elevation is somewhat compensated for by the excessive moisture, a plentiful supply of water being one of the chief requirements for luxuriant orchid growth.

When during early construction days Americans began to arrive in the Canal Zone, the great majority of them unfamiliar with tropical conditions, even the least interested could scarcely fail to take notice of the more conspicuous plants, which were quite unlike anything known to one reared in the temperate zone. Orchids, being as universally associated with conventional conceptions of tropical regions as parrots and monkeys, naturally drew their share of attention, and many temporary residents in the Zone made small collections of them. Without helpful literature upon the subject, and without any person able to furnish information concerning the plants, it was impossible to do more than assemble these amateur collections in the most haphazard way, and little or nothing was added to the recorded scientific information regarding the orchid flora of Panama. When their owners returned to the States, the collections were usually left behind and the plants died for lack of care. The most notable of these local collections of construction days were those assembled by Mrs. D. D. Gaillard and Mrs. H. H. Rousseau, both of which were of considerable size and included many interesting plants. When Mr. Henry Pittier visited the Canal Zone in

1910–11 he obtained from these two collections specimens which were found to represent species previously unknown to science.

At the present time, passing along the streets of the Canal Zone towns, one notices upon porches or hanging in baskets from near-by trees many orchid plants that are kept for their oddity or their handsome flowers. They belong to a small number of well-known species, the botanically more interesting but inconspicuous plants being naturally without interest for the amateur. It may be noted here that in horticultural circles in England and elsewhere a more or less sharp line is drawn between "orchids"—that is, those with showy or odd flowers, worthy of cultivation—and "botanical orchids," which are of interest only to the technical botanist.

To Warscewicz we owe the greater part of the earlier data regarding Panama orchids. He devoted a good deal of time to the exploration of Chiriquí, the region richest in these plants, and probably the most interesting part of Panama for the botanist. In the Canal Zone plants have been gathered by many collectors. Seemann, in 1852, published the first list of Panama orchids, enumerating 104 species. During the progress of the Smithsonian Biological Survey of the Canal Zone in 1910-11, a large collection of the group was obtained by Pittier and Maxon, not only near the Canal but in Chiriquí and in other parts of Panama not visited previously by collectors.

THE POWELL ORCHID GARDEN IN PANAMA.

The major part of our knowledge of the orchids of the Republic of Panama is due to the interest of one man, the result of whose labor is a striking illustration of what may be accomplished by one who has a hobby and follows it intelligently. Mr. C. W. Powell has lived in the Canal Zone since earliest construction days. A man of exceptional breadth of interests, he has always taken a keen interest in general matters relating to natural history, and even in the earliest days he took more than casual notice of the orchids seen in trips through the jungles. From time to time he formed small collections of living plants, some of which he presented to friends, while others were lost by accident. He often laments the fact that he was not then interested in technical classification of the plants, since in the early days, before the forests had been scoured by other collectors and before the virgin forest had been cut, there were doubtless many species that are now extinct and will never be known to science.

About 10 years ago Mr. Powell became seriously interested in orchids, and determined to assemble a complete collection of Panama species. Unfamiliar with the literature and without relations with specialists upon the group, his work was attended by difficulties, but

he assembled living plants in his garden and formed a good library of publications upon orchids. Study of this literature indicated that he had many plants not described in current works. Finally correspondence was established with the English orchidologist, Rolfe, and there was prepared for his study a series of herbarium specimens of the plants as they bloomed; but Rolfe died soon afterward, without having had an opportunity to study the collection. Still later another herbarium collection was prepared, and entrusted for determination to the well-known orchidologist, Schlechter, of Berlin, who published in 1922 a pamphlet of 95 pages enumerating the Powell orchids, which consisted of 184 species, no less than 75 of which were described as new to science.

In more recent years Mr. Powell has forwarded his collection for identification to Mr. Oakes Ames, the most eminent American authority upon this difficult group, and the number of species has increased, until now it amounts to 341. There can scarcely be for any tropical country a record of one person who has contributed so much to the knowledge of the orchid flora, or who has assembled so complete a representation of the group.

The quality of the herbarium specimens prepared by Mr. Powell deserves more than passing mention. Years of experience, through which the best methods have been discovered, combined with attention to details such as other collectors rarely attain, have enabled him to make specimens which are unsurpassed. The color of the flowers is kept perfectly in most cases, and the whole plant preserves its natural aspect. Such results are the more remarkable with a group in which it is extremely difficult to make satisfactory specimens, the plants often having fleshy parts that yield up their moisture only after stubborn resistance. It is very largely because of the difficulty of preparing good specimens that so comparatively small a number of orchids have been collected in explored portions of Central America, a neglect that has extended to many other groups of monocotyledonous plants of a similar nature. It is only by the use of artificial heat that good herbarium specimens of orchids and other fleshy plants can be prepared in tropical regions.

The Powell orchid garden at Balboa is one of the most interesting sights of the Canal Zone, and botanically by far the most remarkable thing to be seen there. It is something unique in tropical America, if not in the whole world.

The garden, situated on the lower slopes of Ancon Hill, is surrounded by a wire-netting fence 8 feet high, covered with vines, and the same netting with its curtain of vines continues overhead. Various climbing plants are used for covering the netting, and by pruning them from time to time the optimum amount of shade or sunlight is obtained.

There are now growing in the garden over 7,000 orchid plants, representing about 400 species. Among these are many that have never flowered, and will, when they blossom, furnish other species records for Panama. Nearly all the plants are from Panama, the only exceptions being some from other parts of tropical America and a few from the Old World, which are grown for their handsome flowers. The garden is a show place in Balboa, visited by many tourists. Most orchids bloom for only a short period, but there are always some in flower at any season of the year. Here in Panama, as in all tropical regions, the great majority of orchids, contrary to ill-informed popular belief, are plants with inconspicuous flowers, without interest to the casual observer. It is true that most of these small flowers, even the tiniest, are strikingly handsome when viewed under a lens. Visitors about to inspect an orchid garden generally anticipate lavish displays of brilliant color, and are sometimes disappointed when faced with actualities, since even in so large an assemblage of orchid plants, and at the most favorable season, the percentage of plants with showy flowers is surprisingly small. For this reason it is desirable to cultivate some exotic plants which can be depended upon to furnish quantities of showy flowers, and thus satisfy those visitors who are interested more in the superficial aspects of the collection than in its true scientific value.

In order to accommodate the large variety of orchids occurring naturally in Panama it is necessary to supply varied conditions for their growth. Tropical orchids are divided into two classes, terrestrial and epiphytic. The former grow in the ground, and in the Tropics these are far less numerous than the epiphytic species. Of terrestrial orchids there are two classes—those with green leaves and stems, which behave like most other plants, and those which are saprophytic, living wholly upon decaying plant matter. Saprophytic orchids, which are not numerous anywhere, are easily recognized by their lack of green coloration.

By far the greater number of tropical orchids are epiphytic, growing upon trunks or limbs of trees, and deriving nutriment chiefly from decaying organic material that lodges about their roots. They are often spoken of as parasites, but no orchids are parasites, our only common representatives of that group being the mistletoes. Epiphytic orchids are sometimes apparently terrestrial, growing upon the ground in beds of mosses and other plants.

In temperate regions all orchids are terrestrial. In the United States epiphytic species are found only in Florida, except for a few that extend farther west close to the Gulf coast. Florida has a rather large number of epiphytic species, belonging to groups that are represented also in Central America. It is worthy of record here that in an orchid list published recently by Ames, about

150 species of orchids are reported for the United States and Canada. Contrary to popular belief, orchids of temperate regions probably average quite as showy as those of the tropics. Few of the latter are more attractive than some of our northern species of *Cypripedium* or lady's-slipper.

It must not be assumed that all epiphytic plants are orchids, as is sometimes carelessly done by residents in the Tropics, just as in cactus regions all plants with spines are likely to be known popularly as cactuses. In warm countries a great number of plants of many widely separated groups assume the epiphytic habit. In tropical America the most noteworthy of these, and those most frequently referred to erroneously as orchids, are bromeliads, or plants of the pineapple family, many of which have exceptionally showy flowers, quite as ornamental as most orchids.

In the Powell garden most of the plants, naturally, are epiphytes. These are grown in baskets filled with sphagnum or upon blocks of wood, suspended from overhead. There is also at one end of the garden a large mango tree upon which a great variety of species have taken root, affording a picture of natural conditions. In the more sunny portion beds are provided for the terrestrial species, which are represented in large numbers. Many epiphytic species, too, prefer a good deal of sunshine, especially the larger, coarser plants. For very small and delicate plants which come originally from wet forests deep shade must be provided. Climatic conditions are favorable in the Canal Zone for orchid cultivation, at least for those species which occur naturally at low elevations. During the summer or rainy season there is a plentiful supply of moisture, too much at times. During the winter months, which constitute the dry season, it is necessary to water the plants daily. Even at so low an altitude, sea level, it has been found practicable to grow most of the montane species brought from the forests of Chiriquí, provided good care is taken of them. There are, of course, insect enemies to be fought—cockroaches, which eat the tender flower buds, and other similar pests that visit the garden, especially at night, and sometimes ruin the blossoms of the most cherished plants whose flowers have been awaited for years. Birds sometimes cause equal harm.

Almost all the orchids known to occur in the whole Republic of Panama may be seen and studied in this garden under the most favorable conditions. For the past ten years Mr. Powell, very often in company with Mr. A. A. Hunter, has conducted systematic exploration in many parts of the country, visiting distant localities, especially the high mountains of Chiriquí. Sometimes the plants are found in full flower in the field, but more often they are not. The living plants are then brought to the garden, where they are carefully tended until they flower, when specimens can be made for study

by specialists. It is only the continued cultivation of the plants in the garden that has made it possible to establish such a record as to the number of Panama species.

Aside from the material gathered upon these expeditions, one or more native collectors have been employed for much of the time. One of these men, a West Indian, himself has become almost an expert upon the native orchids, having made many journeys into the jungle after them and having cared for them in the garden.

Collecting orchids in Panama is not the easy task that it is in Costa Rica, where conditions are more favorable in every respect. Except in the immediate vicinity of the Canal, transportation is difficult. Even here it is usually necessary for the collector to make his way over trails that are negotiable only on foot, or more frequently through regions where there are no trails at all, and it is no easy matter to force one's way through a lowland tropical jungle. Moreover, in the present lowland forests orchids are not plentiful as to either individuals or species. It may be that extended collection has made them scarcer about the Zone, but it seems doubtful that, with the exception of such specially favorable localities as the original Gatun basin, the plants ever were much more plentiful than now. One can travel a long time through the forests along the Canal without seeing any orchids at all, and when some are found they are likely to be perched high on the branches of some giant tree, whence they can be obtained only by felling the tree, which often requires the services of a couple of men for a whole day or more. Even when the tree is felled, the orchids so laboriously obtained may prove worthless. The smaller and more interesting plants can not be seen from the ground, for they grow mostly upon the upper side of the branches and are hidden among other vegetation. Even when a tree can be climbed, usually it is so infested with biting ants or other insects that only by submitting to torture, if even then, is it possible to remain aloft long enough to secure specimens. In Costa Rica one can collect in a single afternoon more orchids than in a whole month in the lowlands of Panama.

COMMON ORCHIDS OF PANAMA

The Panama orchid flora includes a host of showy and interesting species. It is curious that one Old World species seems to have become naturalized. Some years ago Mr. Powell purchased a plant, new to him, from a collector who claimed to have found it in a swamp in the Zone. Upon flowering it was determined as *Phaius tancarvilleae*, a Chinese species. The same plant has become thoroughly naturalized in Jamaica. It is sometimes cultivated for ornament, and probably had escaped from previous cultivation in Panama as in Jamaica.

Most celebrated among Panama orchids is doubtless the *Espíritu Santo*, Holy Ghost or dove orchid (*Peristeria elata*), that often figures upon local illustrated post cards. This plant, which occurs also in Costa Rica, is terrestrial and inhabits the lowland forests. It has been collected so much as now to be rather rare about the Zone. From a cluster of green bulbs rise a few narrow leaves, and a flower stalk 3 or 4 feet high which bears a raceme of fragrant waxy-white flowers about 2 inches broad. The organs in the center of the flower show a striking resemblance to a miniature dove with spread tail and outstretched wings, the head and bill also being perfectly reproduced. It may be imagined in what veneration and esteem such a flower is held by the native people.

In Cattleyas Panama is not fortunate, for only one has been collected, *Cattleya deckeri* (pl. 3, fig. 1), a species related to *C. skinneri* discussed elsewhere, and apparently rare. Mr. Powell, however, has in cultivation some handsome exotic Cattleyas, particularly fine plants of *Cattleya trianaei*, a Colombian species, and one of those most frequently seen in cultivation in the United States.

A peculiarly characteristic Panama plant is *Brassavola nodosa* (pl. 4), which is found nevertheless in many other parts of Central America, northern South America, and even in Jamaica. It grows upon both trees and rocks. The curious thick, stiff leaves are nearly round, but are channeled along the upper side. The delightfully fragrant flowers, 2 to 3 inches long, have greenish sepals and petals and a pure white lip. This is common in the lowlands of Panama, and is one of the few orchids that is plentiful on Taboga Island. A laudable but unsuccessful campaign was once conducted with the purpose of establishing it as the national flower of Panama.

Among the most showy of the local orchids are the species of Oncidium, commonly known as butterfly orchids, a fitting name, since the numerous widespread blossoms, golden yellow and often mottled with brown and red, suggest a cloud of butterflies hovering over the plant. The one here illustrated (pl. 5), *Oncidium powellii*, is known only from Panama, and is one of the host of Panama orchids that appropriately bear the name of the man who has done most toward making them known. The Oncidiums constitute one of the largest orchid groups, about 530 species having been described, all American. They are frequently cultivated in the north and are excellent as cut flowers. In Panama there are numerous species occurring at all elevations. They are abundant locally about the Zone, and someone told me of having seen a year or two ago a swamp near the Atlantic coast where the plants in full blossom abounded to such an extent that their golden color dominated the landscape. In certain species of Oncidium the flower sprays in age reach a length of 10 to 15 feet.

Somewhat suggestive of the Brassavolas is *Brassia longissima* (pl. 6, fig. 1), another lowland species. The flowers are greenish with a yellowish tinge, the lip dotted with purple. The plant is curious because of the unusual elongation of the sepals, these often attaining a length of 7 to 8 inches.

Chondrorrhyncha lipscombiae (pl. 26, fig. 1) is an attractive plant, suggesting the Trichopilias that are so common in Costa Rica. It is a species known only from Gatun Lake. The flowers are white, with a lavender band around the edge of the lip.

Plates 7, 8, and 9 show several Panama species of Epidendrum. This is the largest genus of American orchids, and is confined to the Western Hemisphere. About 750 species have been described, some of them ranging as far north as Florida. There are many species in Panama, and they exhibit great diversity in the form and color of their flowers. *Epidendrum atropurpureum* (pl. 7, fig. 1) is a coarse plant with rather few but large and showy flowers, the sepals and petals being dark purplish and the lip white, with purplish lines in the center. It is plentiful on the dry Pacific slope of Costa Rica, and blossoms during the dry season. I have seen handsome color varieties of it also in Salvador.

Several species of Mormodes are found in Panama. The ones illustrated (pl. 10, pl. 11, fig. 1) have brown flowers of thick texture and striking appearance, remarkable more for their oddity than their beauty. These plants are noteworthy for the fact that they shed their leaves during the dry season, at which time the flowers are produced.

The same habit prevails in a related genus, Catasetum (pl. 11, fig. 2, pl. 12). The species illustrated is a rather attractive plant, with greenish white, fragrant flowers. In this group there are two kinds of flowers, staminate and pistillate (sometimes termed male and female), of quite different appearance. In Cycnoches (pls. 13, 14), too, flowers of two sexes, unlike in appearance, are produced. The sepals commonly are green or greenish, and the lip white. These plants, like those of related genera, are frequently or usually devoid of leaves at time of flowering.

In the case of many of these orchids that have large bulbs (pseudobulbs), organs for storage of moisture, and are leafless when the flowers are unfolded, the bulbs are hollow, at least with age, and inhabited by colonies of characteristic ants that bite severely when the plant is molested. For this reason it is far from pleasant to collect them. The function of the ants is not well understood. Certainly they are not necessary to the growth of the plant, for Mr. Powell states that when preparing plants for the garden, the ants are always removed, notwithstanding which the plants continue to grow luxuriantly.

A similar case of symbiosis occurs in the case of the species of Coryanthes (pl. 6, fig. 2), which are sometimes called bucket orchids, because of the curious form of their flowers. The species figured, which grows on the hills back of Panama City, has clear yellow flowers, which exhibit most remarkable modifications during the process of fertilization. In Coryanthes the huge masses of roots are inhabited by innumerable small ants that are among the fiercest of those found in Panama. So disagreeable is the process of collection that it is almost impossible to obtain the plants, it being stated that the only practical method is to pull the masses from the tree with a rope, then drag them by the rope to a stream, where they may be immersed until the ants have departed. Many similar cases of symbiosis between ants and orchids exist in Central America. The same conditions occur also in numerous other groups of unrelated tropical plants, some of which have special organs for the accommodation of their inhabitants.

Among the vines that cover the trellises in the Powell garden are various plants of Vanilla, of which there are two common species in Panama, *V. planifolia* (pls. 16, 17) with narrow leaves and *V. pompona* with wide leaves. There are several other species of Vanilla in Central America. All are vines which climb high in the trees by means of aerial rootlets, but also root in the ground. The plants are usually plentiful in the lowland forests, and are found almost everywhere about the Canal Zone.

Vanilla is the only orchid with any important economic application. Although so common wild in Central America, it is not grown upon a commercial scale, unless it be in Guatemala, but it is often planted in gardens as a curiosity. The commercial article is obtained chiefly from Mexico, Tahiti, and the East Indies, but some of the vanilla upon the market is an artificial synthetic preparation. The flowers of Vanilla are rather showy. The natural commercial substance is obtained from the seed pods. When these are dried the vanillin, the aromatic principle, crystallizes on the outside of the pod.

One of the most remarkable of Panama orchids is *Selenipedium chica*, discovered in the mountains many years ago by Duchassaing, who reported that the seed pods yielded a flavoring substance similar to vanilla. It was only a few years ago that this species was rediscovered, by Mr. Ellsworth P. Killip, upon Ancon Hill, where, however, it is no longer to be found. The plant reaches a height of 15 feet, and is said by Ames to be the tallest orchid known. The flowers are not very conspicuous, but somewhat resemble those of the lady's-slipper of the United States.

Among the finest of the orchids cultivated by Mr. Powell are several species of Sobralia (pl. 2, fig. 2). They are terrestrial plants, usually forming dense clumps containing numerous stems. The large

flowers are mostly rose or purple, but in some species white, and all are very showy. Some of the species flower almost throughout the year, but the habit of flowering is peculiar. All over a large clump of plants the flowers open, one on each stalk, on a certain morning. They remain open for only a few hours, then close, and fall from the plant unless they have been fertilized. After several days there is another crop of blossoms, but meanwhile not a single flower will have been seen upon the colony.

Worthy of mention because of their oddity are the species of Ornithocephalus, which are not uncommon in both Panama and Costa Rica (pl. 18). The flowers are minute, greenish yellow, and in form bear some resemblance to a bird's head, hence the generic name. The plant is fan-shaped, the leaves being flat and all in one plane, resembling in this respect iris leaves. This fan-shaped arrangement of leaves is found in various other Panama orchids, notably in a diminutive Oncidium that is abundant upon cacao branches at Las Cascadas Plantation. In this the leaves are often not more than half an inch in length, while the flowers, of which there is sometimes only one, are frequently much larger than the plant proper. This is unusual among orchids, since ordinarily small plants have the smallest flowers.

To list all the orchids of Panama or only the more important ones would far exceed the limits of this paper, and would serve no useful purpose, since it would merely furnish a list of uninteresting Latin names. In fact, very few orchids have distinctive English names, and even among gardeners it is the custom to refer to the plants by their generic names, which after all is the only means by which accuracy in plant names may be attained. Photographs give little idea of the modifications exhibited by the flowers, but examination of the plants themselves when in flower is a different matter, for then almost anyone is interested in observing the unbelievable variety presented, a variation in form and coloration not equaled in any other family of plants.

In spite of the great diversity exhibited by orchid flowers, it must be stated that this results only from the modification of organs which are common to other groups of plants. The flower consists of three sepals and three petals, one of the latter being normally very different from the other two and called the lip or labellum. The three stamens, of which one or two are abortive, are united with the pistil to form a column, which also is often specially modified.

ORCHID COLLECTING IN COSTA RICA

Really to see orchids one must go to Costa Rica, where they almost fill the rôle of weeds. After becoming familiar with the profusion of orchids, as to both individuals and species, that exists

here in localities easily accessible, it seems a waste of time to go elsewhere when looking for orchids. Costa Rica possesses many attractive features that make botanical work agreeable, and the expenditure of but little labor yields rich results. The country is easy of access and transportation facilities are comparatively adequate, although not so good as in Salvador; the climate in general is delightful, in many regions temperate rather than tropical; and the people, as the writer can testify from personal experience, pleasant and hospitable to the highest degree. It is a remarkable testimonial to the physical features, government, people, and social conditions of Costa Rica, that whenever an inhabitant of any other Central American state is asked what is the best part of Central America, the answer is almost always if not universally Costa Rica, even in the case of people who have never seen the country. Such is the reputation which Costa Rica enjoys among its neighbors who, after all, are the most competent judges.

Costa Rica has approximately the area of the State of West Virginia, and like that State is preeminently mountainous. To prove the botanical richness of Costa Rica, it is necessary only to state that its known flora includes about 6,000 species of flowering plants and ferns. This number will be greatly increased, for in spite of the vast amount of collecting that has been done, over a long period of years, there are whole mountain ranges of whose vegetation practically nothing has been ascertained. When it is remembered that in the United States and Canada there are only about 16,000 species of plants, and that the United States has 130 times the area of Costa Rica, some idea of the richness of the Costa Rican flora may be formed.

There is probably no other part of all North America of equal extent that can approach Costa Rica in wealth of species, and there is certainly no other region of the continent where so many orchids grow. Scarcely any orchids have been collected thus far in the Cordillera of Talamanca, the most extensive mountain chain and the one containing the loftiest peaks. This area is difficult of access and has hardly been touched by the botanist, although it is likely to prove the most remunerative part of the Republic.

The writer's experiences with orchids in Costa Rica were confined to a few localities that it was possible to visit in two months. These included typical regions of the Atlantic coastal plain, about La Colombiana and Guápiles; numerous localities in the northern Cordillera and in the highlands about San José, the capital; and a single visit to the comparatively dry Pacific coast. At all these places orchids were found in greater or less profusion. Some were in flower, but many more had neither flowers nor seed pods. Although the visit was made during the dry winter months, it seems

unlikely that at any other time of year it would be possible to find a greater proportion of the plants in blossom. At any season some orchids are in bloom, but each species probably has a more or less well defined flowering period, and in order to obtain the complete orchid flora of a locality it would be necessary to visit it every month in the year. Some remain in flower only a few days, while with others the blooming period is greatly prolonged.

PACIFIC SLOPE

So little time was spent upon the Pacific coast, near Orotina, that it is impossible to make any generalizations of value. It may be stated definitely, however, that the whole flora here is far less varied than elsewhere in Costa Rica, and that in a day's collecting one can find only a fraction of the number of plants to be obtained in other parts of Costa Rica in the same length of time. Moreover, the plants are less interesting and consist chiefly of species having a wide distribution in tropical America. Most of the land is now unforested. Where forests do occur they are moderately dense and consist of a limited number of species, many of which lose their leaves in the dry season. In the heavier forest the undergrowth is little varied and lacks many of the conspicuous plants of the Atlantic coast. Ferns are very few, and the species mostly uninteresting. These conditions must be understood as prevailing only at lower altitudes, on the hills and in the plains near the coast. Upon the mountains of the Pacific coastal region conditions are more favorable.

About Orotina orchids were rather plentiful as to individuals, but appeared to represent only a few species. Not many were in flower during the dry season. Most conspicuous was *Epidendrum atropurpureum* (pl. 7, fig. 1). In the forests the orchids are confined mostly to the upper branches of the trees, where it is difficult or impossible to collect them. On some of the small trees scattered about the fields and pastures the case is different. It is a well attested fact that certain species of trees are preferred by orchids, and that there are others upon which they never grow. The favorite tree of all is probably the calabash (*Crescentia cujete*), which is seldom without its quota of orchid epiphytes and often is almost completely covered with them. The mango, strangely enough, is another favorite tree for certain species. About the Canal Zone, where mangoes have run wild through the forests, there is almost always a goodly number of orchid plants upon them. Wild figs, on the other hand, are usually almost or quite free of epiphytes. In general, it seems that smooth-barked trees are little frequented by orchids, although the smoothness of the bark scarcely seems an ade-

quate explanation for this condition, since even the smoothest bark has irregularities sufficient for the lodgment of orchid and other seeds.

ATLANTIC COAST

Over on the Atlantic coast of Costa Rica climatic conditions are very different from those prevailing along the Pacific watershed. Here, although there is some differentiation into dry and wet seasons, there is a copious supply of moisture throughout the year. Even in what may be termed the dry season there are frequent heavy rains, so that at all times of the year the atmosphere is saturated. Such a condition, associated with a high temperature, affords ideal conditions for the development of truly tropical vegetation, which attains a luxuriance unknown in temperate lands.

The lowlands of the Atlantic coast are characterized by heavy forests, naturally more or less like those of near-by Panama, but here there remain vast stretches still untouched by man. The only breaks in the dense forests that cover this part of Costa Rica are the extensive banana plantations, for which the region is famous, and small patches cleared for cultivation of other fruits and of vegetables.

Such forests as these satisfy to the fullest extent one's preconceived notions of what a tropical forest ought to be. The covering of the tree tops is so dense that no sunshine reaches the ground. Even the rain can not fall directly, and during a heavy shower one may walk for miles without becoming wet. Very large trees, with trunks six feet or more in diameter, are frequent, some of them with fantastically buttressed or otherwise supported trunks. Certain trees, notably the Cecropias, which have always seemed to the writer the most characteristically tropical of all Central American trees, are supported by prop-roots, similar in form to those developing in maize. Large, woody vines are characteristic of these forests, and coarse epiphytes, especially aroids and bromeliads. The ground also is well covered nearly everywhere, mostly with large herbs, among which ferns are usually conspicuous, as well as numerous sorts of palms. Some of these plants have showy flowers, but more often the blossoms are small and inconspicuous. In the heavy lowland forest one may look in every direction and see no sign of color other than the dull, dark, monotonous green that is characteristic of tropical American forests, and quite different from the lighter and livelier green of the forests of the United States.

There are a good many orchids in this part of Costa Rica, and there must be many undescribed ones, for the region has been little visited by botanists, chiefly because of a wholesome fear of malaria, which is all too prevalent at such elevations. In the case of other groups

of plants it is certain that the flora is of the highest interest. Collecting orchids here is attended with much the same difficulties as upon the Pacific coast, for the plants perch upon the highest branches where they can scarcely be reached. When one is so fortunate as to find an area recently cleared, where the fallen trees have not yet been burned, a large collection may be gathered in a short time. Some of the orchids grow low upon the tree trunks, and can be reached from the ground. It is not uncommon to find orchids normally terrestrial that have here taken to growing upon tree trunks.

HIGHLANDS OF CENTRAL COSTA RICA

It is to the mountains one must travel if large quantities of orchids are to be seen, and there not even the least energetic collector can fail to find them. Of all Costa Rica, the central uplands are the most attractive part. The climate in many localities is ideal, and the landscape sufficiently varied and pleasing to satisfy the most fastidious visitor. All or nearly all the usual tropical insect and other pests are left behind, and one may wander about with less discomfort than in most parts of the United States. There are so many beautiful places that it is impossible to determine which should head the list. What can be lovelier than the Valley of Orosi, south of Cartago; or Cartago itself, lying at the foot of the Volcano of Irazú? Central America is rich in cities with beautiful sites, but none of them can surpass the Costa Rican capital, San José.

This portion of Costa Rica has a temperate rather than a tropical climate. Freezing temperatures are unknown, but upon the tops of the high volcanoes frosts occur. In this temperate belt and just below its lower limits, or even in the colder upper belts of the mountains, orchids attain their greatest profusion. All this region was once covered by dense humid forest, no doubt, but now large areas, in fact the greater portion, have been cleared to make way for the coffee fincas which furnish the chief wealth of the country. At still higher altitudes the forest has been replaced by meadows over which graze the herds of cattle that are the basis of a substantial industry in milk, cheese, and butter, such as has been developed nowhere else in Central America.

The abundance of material here available for study under such exceptional physical conditions must arouse the enthusiasm of any botanist. The variety of plants is so great that at first one is overwhelmed, and can only wander about bewildered and unable to fix attention upon any particular plant.

Only a few hours' ride from San José over a good road brings one to La Palma (pl. 19), a classic locality for Costa Rican plants, visited by almost every botanist who has worked in Costa Rica, yet of

such wealth that it is still far from exhausted. One rides at first through comparatively level country, planted with coffee and groves of fruit trees, then through fields of corn, until finally one reaches a rather definite line at which there is evidence of a moister climate. Beyond this point there are few cultivated fields, but instead pastures full of cattle. La Palma lies in a gap between the volcanoes of Barba and Irazú. The pass between these peaks has an altitude of about 5,700 feet. Through this opening clouds pour from the plains of Santa Clara, which stretch toward the Atlantic coast; they lodge here and shed their rain. It is said that it is always raining at La Palma. No matter how clear the day at San José, looking toward La Palma one always sees low-hanging clouds. Riding along the road one comes suddenly into this cloud zone, out of the sunshine into a penetrating fog, with cold drizzling rain, and often an accompaniment of wind. At night this combination is dismal and uncomfortable beyond description, and even in the day the effect is dreary enough; yet the sun does shine sometimes at La Palma, and then the scene is beautiful. The temperature is so low that one is never comfortably warm. The meadows, mostly of imported grasses, clovers, and other European plants, dotted with dandelions, buttercups, and violets, are green throughout the year. The continuous rainfall has saturated the meadows so that they are like sponges soaked in icy water, into which one sinks at each step. There are small rills on every side. About the meadows are banked dark masses of trees, that also fill the uncleared ravines.

Clearing does not seem to have injured the flora; rather it has probably improved it. Many plants, including some of the most showy ones, do not reach their best development in deep forest, but require a greater amount of light than is available there. These have found a favorable environment at the forest edge. Many orchids belong to this class; indeed, orchids generally, except some of the smallest and most delicate, do not seem to thrive in heavy forest, and in general orchid collecting gives better results at the forest edge and on the isolated trees that dot the meadows.

Take any one of these trees or one of the old stumps, and examine it at leisure. It will be found that each tree is a veritable flower garden. Each has a flora different from that of its neighbor. The best method of collecting is to take a small area and "comb" the trees, one by one. There is no need to cover a large area; ability to climb trees is the most important requirement. The trees are small and gnarled, resembling old apple trees. They are of many species, but often it is difficult to determine what the tree itself really is, so nearly concealed is it under a burden of alien vegetation. There are some true parasites here, mistletoes with masses of yellow or red flowers, but most of the covering con-

sists of epiphytes, loose cushions and pendants of mosses and hepatics, gray lichens, and masses of herbs and shrubs of the most heterogeneous family relationship. Some of the invading shrubs are nearly as large as the host itself. Many are noteworthy for their gorgeous flowers, and if this were a tropical forest it really would satisfy popular pictures of the Tropics. Usually yellow flowers predominate in any locality, but such is not the case here. Although yellows are not absent, they are not so conspicuous, at least in winter, as the reds supplied by innumerable plants of the heath family. These furnish such an abundance of red as one expects never to find in nature. Some of the lobelias are equally showy, and there are also other plants with red blossoms. Blues are as scarce as elsewhere, but there are many plants with attractive white flowers.

On all these moss-covered trees there is an abundant supply of ferns and, last but not least, of orchids. The profusion of orchids is truly bewildering. Occasionally there is one with showy flowers, but more often they are small plants, often only 1 or 2 inches high, with miniature blossoms. Every branch bears a copious supply of them, and the variety is infinite. If one spends the whole day hunting them, at evening one will still be finding new forms. Some species are plentiful and quickly recognized, but others are so rare that one may search all day without finding a second plant. When one realizes that in Costa Rica there are many hundreds of square miles of equally rich orchid territory, it will be understood why it is that every new collector finds many novelties.

Well within the forest, which is always dripping wet, there are many orchids and other plants upon the trees. The individual plants are so entangled that there is difficulty in separating them. Their roots are bedded in masses of decaying vegetable matter, and when a clump is pulled down from above, a shower of débris falls into one's eyes. Some terrestrial orchids occur, but the species are unimportant in comparison with the epiphytic ones.

All around La Palma there are many other favorable localities, several of which were visited by the writer. At La Hondura, over the pass from San José and on the Atlantic slope, the flora is almost unbelievably varied and rich, and years of collecting will be insufficient to exhaust it. The elevation at La Hondura is less than at La Palma, but the precipitation is as great, and there can be no better place in which to look for orchids.

It is interesting to see how remarkably the plants change from one locality to another, even at a distance of only a few miles. Plants that are abundant in one place may not be found at all at a near-by locality, and this is frequently the case even with trees and other large and important species. With orchids elevation seems to

be a matter of great importance. There is apparently an optimum elevation at which they reach their best development. For the La Palma region this must be at about 6,000 feet. At another locality only a very few miles away, but of slightly greater elevation, orchids were found to be far less plentiful, although the other vegetation was luxuriant and attractively varied.

At higher elevations the scarcity of orchids is still more pronounced. Upon the upper slopes of the Volcano of Poás, one of the most remarkable natural monuments of Central America, although there are humid forests, and trees loaded with epiphytic vegetation, orchids are few in both species and individuals. Toward the summit of the Volcano of Turrialba their absence is even more striking, and not over half a dozen species were found. This is the more remarkable since the wet forests of Turrialba are richer in ferns than any locality seen by the writer in Costa Rica, and other epiphytes are present in quite as great abundance as at La Palma. It must be that the altitude is too great and the temperature too low for the needs of orchid growth. It seems certain, therefore, that the expectations of those who have stated that a whole new orchid flora would be found on the higher slopes of the Central American mountains are doomed to disappointment.

There are many other localities in central Costa Rica that furnish a wealth of orchids. In the wet mountains south of Cartago their variety is perhaps as great as at La Palma, although individuals are hardly as numerous. It may be noted, too, that most of the species found in the latter region are different from those of La Palma. Even in the immediate vicinity of San José and Cartago, especially about the latter city, orchids grow upon nearly all the roadside trees, and even upon fence posts. At La Palma one could make a fine collection without ever leaving the wagon road.

Costa Rican conditions are extremely favorable for forming a living collection of orchid plants, yet little has been done in this direction. Some years ago Doña Amparo Zeledón assembled in San José an extensive collection of the more showy species, the plants having been collected principally by Werckle. Specimens from plants of this collection have been made the types of new species by Schlechter. At the present time, because of the absence of its owner, this collection has unfortunately deteriorated, and comparatively few plants remain.

Frequently about San José and Cartago one sees small collections of orchids about the houses, most of the plants those which produce conspicuous flowers. One of the finest local collections is that of Father Benavides, in Heredia. This consists of a very large number of plants and includes a wonderful display of Cattleyas and other

large-flowered local orchids. Father Benavides' plants are all grown upon pieces of tree-fern trunks, which are said to furnish the best medium for the growth of epiphytic species.

The most enthusiastic local student is Mr. C. H. Lankester, of Cartago, an Englishman who has spent many years in Costa Rica. A naturalist in the best and widest sense of that word, he has devoted much time to the study and collection not only of orchids but of birds and butterflies, in all of which he has made notable discoveries. His present collection of living plants contains a host of beautiful and interesting forms. Besides local species, he has fine exotic plants, including some of the most handsome Cattleyas. He has carried on experiments in hybridization, and has planted upon trees about his finca hybrids and exotic species, in an attempt to naturalize them. Mr. Lankester has forwarded many living orchids to the Kew Gardens, and from his collections there have been described numerous Costa Rican novelties, including the new genus Lankesterella.

SOME SHOWY COSTA RICAN ORCHIDS

Costa Rican orchids are famed for their variety and for the beauty of some of the species. They include all or most of the groups already mentioned from Panama, besides many that do not occur in Panama. Most showy of all are the Cattleyas, which are unusually abundant in Costa Rica.

To these flowers there is given locally the name *guaria*, an indigenous term. The most plentiful is the *guaria morada* or purple Cattleya, *C. skinneri* (pl. 20), a species which has already been mentioned as occurring in Salvador. In Costa Rica it is still more abundant, growing commonly all over the Pacific slope. The plant is a great favorite locally, and for this reason is seldom seen wild in the more thickly populated districts. At Escazú, a small village near the capital, I have seen a greater profusion than anywhere else, and a show of great beauty in March and April, when the flowering season is at its height. There is scarcely a home that does not own at least a few plants, fastened upon trees in the dooryards, growing upon the tile roofs, or forming dense masses along the tops of the adobe walls that inclose the gardens.

One of the striking features of San José is the great number of florists who have gardens or *jardinerías* where flowers are grown for sale. All over Central America the production of cut flowers is an industry of considerable importance, and in San José more so than anywhere else, for the gardens here seem almost without number. Most of the flowers grown for sale are of common sorts, such as roses, carnations, and lilies, and they are planted in great abundance. The

cultivation of Cattleyas and other orchids for the sale of their flowers is common, and in some of the commercial gardens there are magnificent displays. The fine clump of *Cattleya skinneri* illustrated in Plate 20 is from such a garden, owned by an American citizen of Danish origin. In this Milflor garden there is a long avenue, lined on each side with trees whose trunks are completely covered with this Cattleya, affording during the flowering season a gorgeous show of color. In other gardens the display is almost equally fine. Some of the plants are as large as a washtub and produce hundreds of blossoms. These last for weeks and are of delicate shades of rose purple.

The genus Cattleya consists of 30 to 40 species, all of which are American, extending from Mexico into South America. They are the favorite orchids for cultivation in the United States and Europe because of their handsome flowers and even more, perhaps, because of their easy culture. They are favorites with the hybridizer, and numerous fine artificial forms have been produced by hybridization. Many living Cattleya plants are exported from tropical America for growth in northern countries. Their flowers are the orchids most commonly sold in flower shops in the United States, and those generally associated in the popular mind with the word orchid.

The most prized locally of the Costa Rican orchids is the *guaria blanca* or white Cattleya. It is only a color variant of *Cattleya skinneri*, but a very distinct one, for the flowers are pure white. It is a strikingly beautiful plant, and occurs in the wild state, although it is so much sought after that it is now hard to find. Even in Costa Rica the plants are held at dear prices, and I was informed of one fine clump for which $150 had been paid.

The third Costa Rican Cattleya is probably the finest Central American orchid, and is commonly considered the most gorgeous of all the Cattleyas. It is the *guaria Turrialba* or simply *Turrialba*, the Turrialba Cattleya, *C. dowiana* (pl. 21). It takes its name from the fact that it grows chiefly about the lower slopes of the Volcano of Turrialba, on the Atlantic side of Costa Rica. The writer was fortunate enough to find a vigorous plant, with buds, in the forest near Guápiles. This Cattleya also has been so much hunted by commercial collectors that it is now considered rare. Its sepals and petals are nankeen yellow, and the ruffled lip is of a rich deep crimson purple, veined with gold. In color it is quite unlike any of its relatives, and none of them is so richly decorated. When first described in Europe by its discoverer, Oersted, botanists were skeptical as to the accuracy of his description. Although the Turrialba Cattleya is confined to Costa Rica, several varieties of it have been reported and introduced into cultivation from Colombia, one of them with pure yellow flowers.

Next to the Cattleyas, the plants most esteemed for cultivation in Costa Rica are the Trichopilias. Of these the most common is *Trichopilia suavis* (pl. 22), a species occurring also in Panama. It is rather frequent in Costa Rican forests at lower altitudes, and it is possible to find wild plants quite as fine as those of gardens. The flowers have white or creamy sepals and petals; the lip has a yellow throat, with rose markings upon a white ground. Trichopilias are well known locally, and even in remote country districts small children know them by their Latin name.

Other showy species are found among the Odontoglossums, one of the most popular groups in cultivation of all American orchids. *Odontoglossum schlieperianum* (pl. 23, fig. 1) has yellow flowers, the segments cross-barred with deep purple. The Stanhopeas are noted as including many fine plants that are favorites in cultivation. The one illustrated (pl. 24, fig. 1) has flowers about 4 inches broad, in which the sepals and petals are pure white, with purple dots, and the lip white with yellow base and purple mottlings.

Many other Costa Rican orchids deserve mention, but without illustrations they would be no more than mere names. The Miltonias are almost as beautiful as the Cattleyas, and there are other little known plants that are noteworthy because of their exceptionally handsome blossoms. *Epidendrum endresii*, a dwarf plant with clusters of pure white flowers, handsomely spotted with purple, is one of the most delicately beautiful of all. The most common and striking orchid of the Meseta Central of Costa Rica is *Epidendrum radicans*, which is found nearly everywhere at certain elevations. It is a terrestrial plant, its slender, erect or climbing stems, with their numerous thick aerial roots and broad thick leaves, topped with a cluster of orange-scarlet flowers. In many localities it almost assumes the character of a weed, and grows in the greatest abundance. The writer was shown an unusually interesting and large colony by Mr. Lankester in a curious habitat upon his finca at Las Cóncavas. Here it occurred in great profusion in a marsh along with a Habenaria and, strangely enough, the common royal fern, just as we find the last in the eastern United States. Such a habitat is quite unusual, for ordinarily the scarlet *Epidendrum* inhabits rather well drained banks and meadows.

Another fine Epidendrum is *E. lindleyanum* (pl. 23, fig. 2), a plant sometimes referred to the genus *Barkeria*. The specimens illustrated were obtained at Orosi by Don Anastasio Alfaro, director of the Costa Rican National Museum, an enthusiastic orchid collector. In this plant the flowers are rose purple, and the petals and sepals well over an inch in length. *Epidendrum ciliare* (pl. 24, fig. 2) is a widely distributed plant in tropical America, and one of the

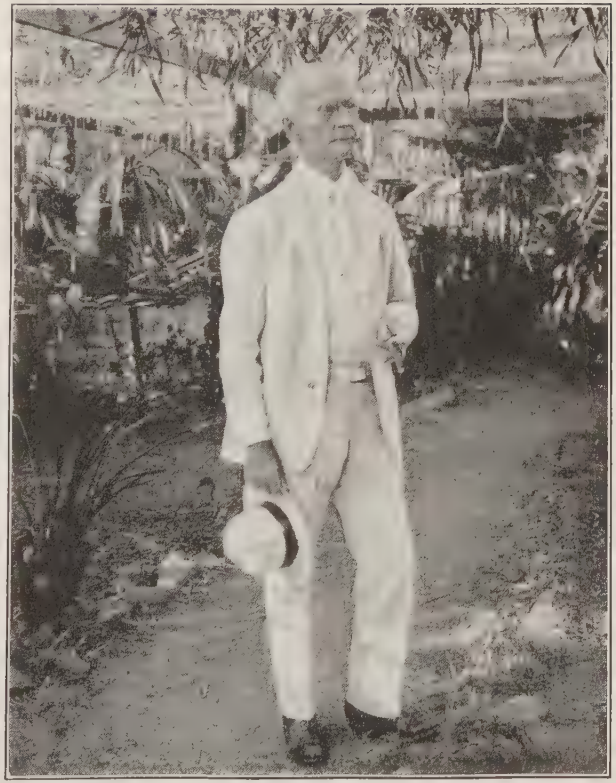
most attractive of its group. The sepals and petals (about 3 inches long) are greenish yellow, and the pure white lip is divided into many long threadlike lobes.

The species of Acineta illustrated (pl. 25) is a relative of the Gongoras (pl. 15) that are so common in Panama. The Pleurothallis (pl. 26, fig. 2) is a representative of one of the largest genera of of American orchids. This one, however, is scarcely typical of the genus, since it is a plant several feet high, while the other species seldom attain a height of more than 2 or 3 inches. The species of Pleurothallis, although highly interesting to the botanist, are of no value for cultivation.

In view of the large collections of orchids that have been made in recent years in Costa Rica and elsewhere in Central America, it is sometimes asked by persons unfamiliar with the region whether there may not be danger of their extinction. It may be stated that there is no danger of this, so far as the operations of collectors for study purposes are concerned. Commercial collectors hunt only the showy plants, and even these are probably in no immediate danger of extermination. In the case of herbarium collections, only a few specimens of a given species are taken, and there is no possibility of exhaustion from this source. The greatest menace is the clearing of the forests for agricultural purposes, which in Salvador has proceeded so far as almost to eliminate the primeval vegetation; but the rapid extension of the agricultural areas in Central America is far more important and desirable, it is needless to remark, than the preservation of orchid species. In favorable localities in Costa Rica it would be possible to gather in a short time many tons of orchid plants without exhausting the supply. When we remember the incredible number of seeds produced by orchids, we wonder only that they do not dominate vegetation everywhere in the Tropics.

1. VIEW OF EXTERIOR OF THE POWELL ORCHID GARDEN, BALBOA, CANAL ZONE. THE VINE-COVERED TRELLISES, SEEN FROM A DISTANCE, SUGGEST A VINEYARD

2. VIEW IN THE POWELL ORCHID GARDEN. OVER 7,000 PLANTS ARE GROWING HERE, REPRESENTING NEARLY ALL THE ORCHIDS KNOWN TO OCCUR IN PANAMA



1. MR. C. W. POWELL IN HIS ORCHID GARDEN AT BALBOA, CANAL ZONE

2. SOBRALIA POWELLII. GATUN LAKE, CANAL ZONE. FLOWERS WHITE WITH BRONZE THROAT. SLIGHTLY REDUCED

1. CATTLEYA DECKERI. PANAMA. FLOWERS ROSE-PURPLE. MUCH REDUCED

2. TRICHOPILIA MARGINATA. PANAMA. FLOWERS WHITE, WITH DEEP RED THROAT. ABOUT ONE-THIRD NATURAL SIZE

(Photographs from Mr. C. W. Powell)

BRASSAVOLA NODOSA. PANAMA. LIP PURE WHITE. MUCH REDUCED

(Photograph from Mr. C. W. Powell)

ONCIDIUM POWELLII. PANAMA. ONE OF THE BUTTERFLY ORCHIDS. FLOWERS BROWN AND YELLOW. ABOUT HALF NATURAL SIZE

(Photograph from Mr. C. W Powell)

1. BRASSIA LONGISSIMA. PANAMA. FLOWERS YELLOWISH GREEN, THE LIP MARKED WITH PURPLE. MUCH REDUCED

2. CORYANTHES HUNTERIANUM. BUCKET ORCHID. PANAMA. FLOWERS YELLOW. MUCH REDUCED

(Photographs from Mr. C. W. Powell)

1. EPIDENDRUM ATROPURPUREUM. A COMMON SPECIES OF PANAMA AND COSTA RICA. SEPALS AND PETALS PURPLISH BROWN; LIP WHITE, WITH ROSE LINES. NATURAL SIZE

2. EPIDENDRUM STAMFORDIANUM. PANAMA. FLOWERS WHITE AND ROSE-BROWN. NATURAL SIZE

(Photographs from Mr. C. W. Powell)

EPIDENDRUM PACHYCARPUM. FRIJOLES, CANAL ZONE. FLOWERS WHITE, THE LIP VEINED WITH PURPLE. NATURAL SIZE

EPIDENDRUM VARIEGATUM. CANAL ZONE. FLOWERS GREENISH WHITE, WITH DARK PURPLE MARKINGS. NATURAL SIZE

(Photograph by Mr. H. Pittier

MORMODES BUCCINATOR. CANAL ZONE. A PORTION OF THE PENDENT INFLORESCENCE. FLOWERS VARYING FROM BRIGHT YELLOW TO DARK BROWN. NATURAL SIZE

(Photograph by Mr. H. Pittier)

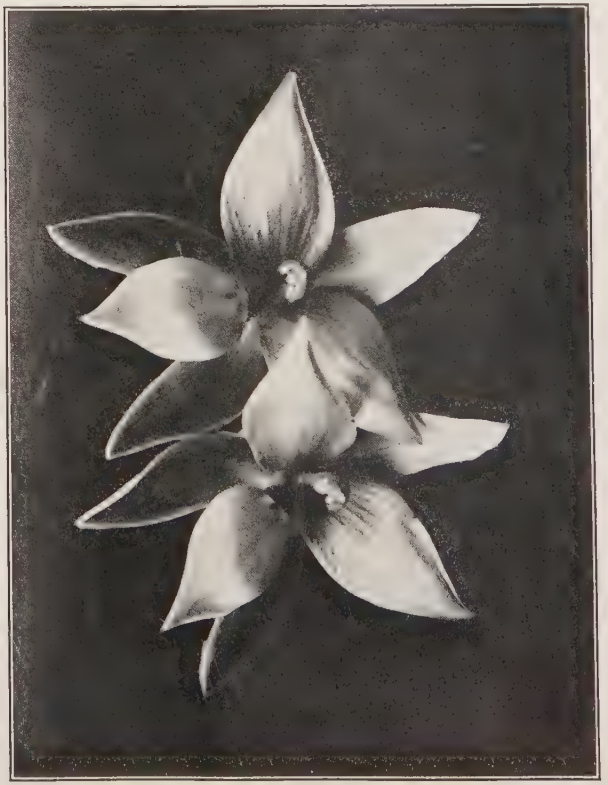
1. MORMODES IGNEUM. PANAMA. FLOWERS BROWN. ABOUT HALF NATURAL SIZE

2. CATASETUM WARSCEWICZII. PANAMA. FLOWERS GREENISH WHITE. ABOUT HALF NATURAL SIZE

(Photographs from Mr. C. W. Powell)

CATASETUM VIRIDIFLORUM. CANAL ZONE. FLOWERS GREENISH YELLOW. NATURAL SIZE

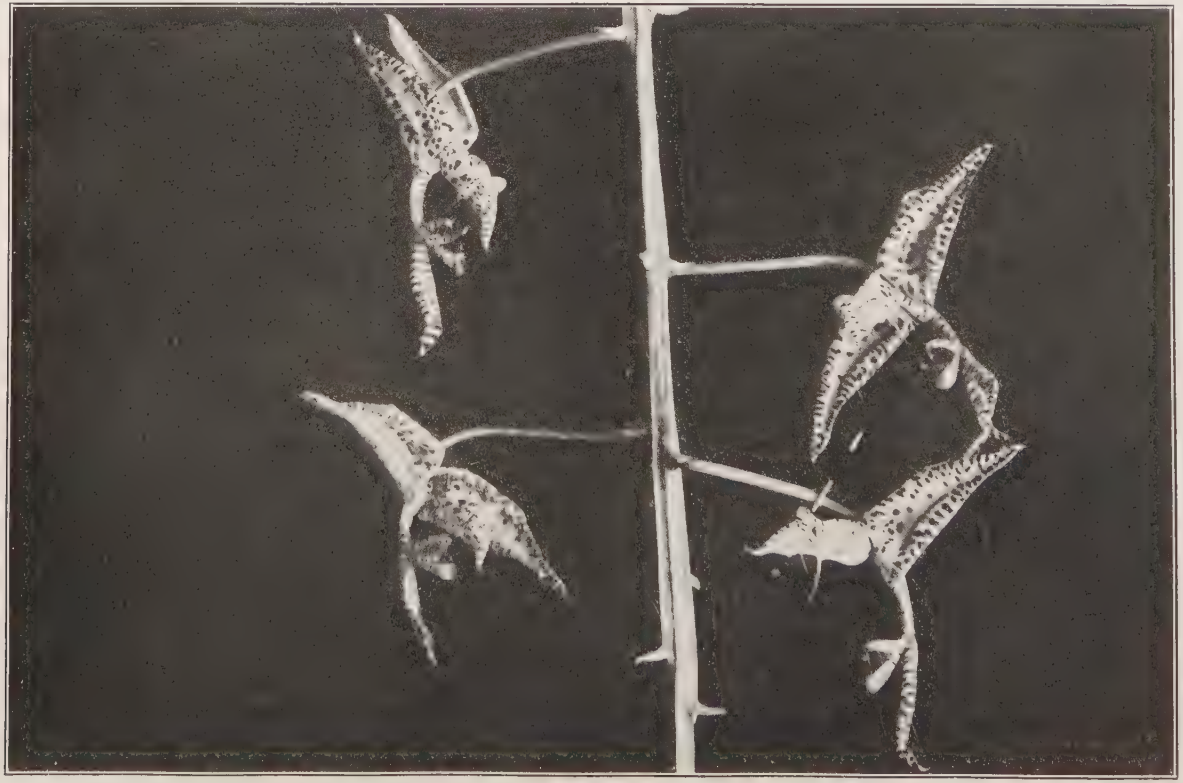
1. CYCNOCHES WARSCEWICZII. PANAMA. STAMINATE FLOWERS. LIP WHITE; SEPALS AND PETALS YELLOW. ABOUT TWO-THIRDS NATURAL SIZE



2. CYCNOCHES GUTTULATUM. PANAMA. PISTILLATE FLOWERS. NATURAL SIZE

(Photographs from Mr. C. W. Powell)

CYCHNOCHES VENTRICOSUM. CANAL ZONE. FLOWERS GREENISH YELLOW



GONGORA QUINQUENERVIS. CANAL ZONE. FLOWERS GREENISH YELLOW WITH PURPLE-BROWN SPOTS. NATURAL SIZE

(Photograph by Mr. H. Pittier)

VANILLA (VANILLA PLANIFOLIA). GUATEMALA. THE FLOWERS ARE GREENISH WHITE. ABOUT HALF NATURAL SIZE

(Photograph from U. S. Department of Agriculture)

VANILLA (VANILLA PLANIFOLIA). CANAL ZONE. NATURAL SIZE

(Photograph from U. S. Department of Agriculture)

ORNITHOCEPHALUS ELEPHAS. CANAL ZONE. FLOWERS GREENISH YELLOW. NATURAL SIZE

VIEW AT LA PALMA, COSTA RICA, ONE OF THE BEST ORCHID REGIONS OF CENTRAL AMERICA. ALL THE TREES ARE LOADED WITH ORCHIDS AND OTHER EPIPHYTES

(Photograph from U. S. Department of Agriculture)

CATTLEYA SKINNERI. SAN JOSE, COSTA RICA. FLOWERS ROSE-PURPLE

(Photograph by M. Gómez Miralles)

CATTLEYA DOWIANA. COSTA RICA. SEPALS AND PETALS NANKEEN YELLOW; LIP CRIMSON-PURPLE, VEINED WITH GOLD. MUCH REDUCED

(Photograph by M. Gómez Miralles)

TRICHOPILIA SUAVIS. COSTA RICA AND PANAMA. FLOWERS WHITE WITH ROSE MARKINGS. ABOUT ONE THIRD NATURAL SIZE

(Photograph by M. Gómez Miralles)

1. ODONTOGLOSSUM SCHLIEPERIANUM. COSTA RICA. FLOWERS YELLOW, WITH DEEP PURPLE MARKINGS. ABOUT TWO-FIFTHS NATURAL SIZE

2. EPIDENDRUM LINDLEYANUM. OROSI, COSTA RICA. FLOWERS ROSE-PURPLE. ABOUT ONE THIRD NATURAL SIZE

(Photographs from Don Anastasio Alfaro)

1. STANHOPEA ECORNUTA. SARAPIQUI, COSTA RICA. FLOWERS WHITE, WITH PURPLE DOTS. ABOUT HALF NATURAL SIZE

2. EPIDENDRUM CILIARE. CACHI, COSTA RICA. SEPALS AND PETALS GREENISH YELLOW, THE LIP WHITE. MUCH REDUCED

(Photographs from Mr. C. H. Lankester)

A SPECIES OF ACINETA. COSTA RICA. FLOWERS YELLOW AND BROWNISH RED, FLESHY. REDUCED

(Photograph by M. Gómez Miralles)

1. CHONDRORRHYNCHA LIPSCOMBIAE. CANAL ZONE. FLOWERS WHITE, THE LIP EDGED WITH LAVENDER. MUCH REDUCED

(Photograph from Mr C. W. Powell)

2. PLEUROTHALLIS GRANDIS. CACHI, COSTA RICA. PLANT ABOUT 3 FEET HIGH; FLOWERS PURPLE-BROWN. MOST SPECIES OF PLEUROTHALLIS ARE SMALL PLANTS, 2 TO 3 INCHES HIGH

(Photograph from Mr. C. H. Lankester)

SKETCHES FROM THE NOTEBOOK OF A NATURALIST-TRAVELER IN OCEANIA DURING THE YEAR 1923

By Casey A. Wood

Since every visitor to Polynesia and Australasia must perforce say something about Captain Cook, the mutineers of the *Bounty*, and the Southern Cross, I need not apologize for beginning my observations with a few notes on these attractive subjects.

Imprimis, I discovered that my recollections of the three voyages of Cook and of his remarkable scientific career were not as fresh as they ought to be for one who proposed to travel over that quarter of the globe he described so clearly over a hundred years ago. Indeed, after reading the account given in his "Voyages," one feels that very little of importance has since been published touching the early history of the South Seas, many of whose islands he placed on the map. Certainly, since the publication of his reports we have not learned much more concerning the customs and lives of the natives.

James Cook, son of a common agricultural laborer, was born in Yorkshire, October 27, 1728. His parents tried to fashion him into a haberdasher, but the lure of the ocean was too much for him and them and—an old, familiar British boy's tale—he quit the trade and went to sea as a common sailor. After various adventures along the British coast and in the Baltic he volunteered as an able seaman in the royal navy, assisted at the capture of Quebec, charted the lower St. Lawrence and the shores of Newfoundland and succeeded in proving to his superiors that he was no idler in his chosen profession but aspired to the highest command possible to a self-taught mariner. When, in the year 1768, the Government, at the suggestion of the Royal Society, decided to send an expedition to the South Seas for the purpose of observing the transit of Venus over the sun's disk, Lieutenant Cook, then 40 years of age and in the full possession of his powers, was placed in command. From that date the Pacific and its wonderful islands became his special domain and his accounts of his three voyages of observation and discovery make fascinating reading. It must be remembered that at least two of the adventures were undertaken in the company of well-trained natural-

ists, students of Linnaeus, who probably "checked up" most of the reports on animal life with which his pages are crowded. On June 25, 1776, Captain Cook sailed on his last voyage—an expedition fitted out by the British Government for the chief purpose of discovering a northwest passage from the Pacific side — to do from the westward what Franklin and others were later to attempt from the east. On Valentine's Day, 1779, he was clubbed to death by the natives of Hawaii, with whom his men had an altercation—a most tragic end for a man who had uniformly treated the aborigines of the lands he visited with humanity and tact and with such a just regard for their peculiar viewpoints.

His accounts abound with references to the abundant faunal, especially the avian, life of Polynesia. Listen, for example, to this extract from his "First Voyage": "Northward from Botany Bay * * * we have for some days past seen the sea birds, called boobies, which from half an hour before sunrising to half an hour after were continually passing the ship in large flights, from which it was conjectured that there was a river or inlet of shallow water to the southward, where they went to feed in the day, returning in the evening to some islands to the northward." Of course these were not *Sula bassana*, that exclusive Atlantic bird, but the Booby gannet—*Sulu leucogastra*—seen on both sides of the American Continents. I am morally certain that it was some descendants of these same boobies that we saw as we sailed the same waters.

For his second voyage the Government employed H. M. Barque *Endeavour*, 370 tons, complement 84. With this equipment the transit was successfully witnessed (on Tahiti) and duly reported, in the Philosophical Transactions for the year 1771.

Several designations remain to mark this adventure: Two of these are, the group name, Society Islands, from the Royal Society; and Point Venus, about ten miles from Papeete, where the transit was observed. The British were so well pleased with Cook's part in this undertaking that they placed him in command of a second expedition to complete the discovery of another continent that most geographers believed existed in the Southern Hemisphere. Two ships were this time commissioned for the purpose, the *Resolution*, 462 tons, and the *Adventure*, 336 tons. They were well equipped and liberally provided with scientific apparatus and stores. As with the reports of the first voyage so is the second replete with clear descriptions of the fauna of the islands visited. As they sailed south from New Zealand, for instance, they fell in with several large islands and, at last, with a quantity of loose ice. Here they saw "gray albatrosses, blue peterels, pintadoes, and fulmers." Still later they got two of the Antarctic petrels. "These are about the size of a large pigeon; the feathers of the head, back, and part of the upper

side of the wings are of a light brown, the belly and underside of the wings white; the tail feathers are also white, but tipped with brown. These birds are fuller of feathers than any we had hitherto seen; such care has nature taken to clothe them suitable to the climate in which they live." And the foregoing description has not since the days of Cook been much improved upon.

Probably Captain Cook's "blue peterels" were of the genus *Prion*—the small dove petrels, whose upper surface is ashy blue, with white below. They are only about 12 inches long, with a jet-black, pyramidal band stretching from one leg to the other across the rump, which shows very plainly during flight.

The "Antartic peterel" may be that allied species, *Prion desolatus*. They do not attend ships, being suspicious of man and all his works, but follow the whale and feed upon not the crumbs but the more substantial fragments that fall from his ample maw. Hence their vulgar name of whale bird. I have never seen this species alive, but they are said to be nocturnal in their habits. The "pintado" is more certainly the pretty little cape petrel—*Daption capensis*, or cape pigeon, so called from its superficial resemblance to a pigeon, with head spotted with black and a pure white belly. This small petrel, well known to travelers in the South Pacific, eagerly feeds on scraps thrown from vessels, and even dives after them, like a duck. If caught, *Daption*, like others of his kind, tries to defend himself by ejecting an offensive fluid at and over his captor. Although essentially an Antarctic bird, it is occasionally seen as far north as Ceylon and California.

Although Captain Cook did not find a northwest passage, even with the aid of his good ships *Resolution*, of 462 tons, and *Discovery*, 300 tons, yet he made for his Government many other discoveries that were, perhaps, of greater value.

It may with truth be claimed that the traveler who first saw and described the famous constellation, the Southern Cross, was an American. When Americo Vespucci, on his first voyage, saw the constellation, he wrote in triumph that he had beheld the Cross—and Dante's "four stars." A friend has drawn my attention to the poet's description:

> To the right I turned and fixed my mind
> On the other pole attentive, where I saw
> Four stars ne'er seen before save by the ken
> Of our first parents.
> Heaven of their ray seemed joyous.
> O, thou northern site, bereft
> Indeed, and widowed, since of these deprived."

This quotation is from Canto I, of the "Purgatorio," in Cary's translation.

The Cross lies directly south of the constellation Crater, and about 30° of the pole. The precession of the equinoxes is carrying the Cross steadily southward, and it is said to be a fact that the constellation was last seen on the horizon in the latitude of Judea about the time of Christ's crucifixion. I remember that at the season of the year we were at Assouan the four stars (perhaps only two of them, really) were barely visible on the horizon for a short time in the early evening. I do not agree with Pigafetta that it is such a *Croce maravigliosa*, but then I was more gradually introduced to it than he, and I didn't see it with his deeply religious and fervent eyes.

It must not be forgotten that Job saw the Cross as a familiar heavenly series in his northern skies, as did many another ancient and reliable astronomer, and yet they were not much impressed by this kite-like group. Let me add that of the four stars that outline the Cross the third largest (Gamma, at the top of the Cross) is orange-colored; the others are white.

The *Breadfruit tree*, as I have seen it in the West Indies, South America, and on these islands, is a very handsome ornament of the landscape. The common variety (*Artocarpus incisa*) may grow to a height of 50 feet and, with its long, dark, glossy leaves, at once attracts attention. The fruit is round-oval, is about the size of a child's head, and is covered with lozenge-shaped elevations. The unripe fruit is green; yellow when mature. For cooking, it should be gathered before it is fully ripe. The fruit is then baked and served with the rind, after the manner of our squash. Stones are heated in the usual Polynesian fashion (or a more up-to-date oven is used), the breadfruit is cut in three or four slices, and then alternate layers of hot stones, leaves, and cut fruit are well covered with leaves and earth and left to cook in their own juices. Prepared in this fashion the pulpy interior is a faintly sweet, starchy substance suggesting the crumb of a wheaten loaf. I can not say that I regard it as more than a poor substitute for our white bread.

Alfred R. Wallace, in his Malay Archipelago, rates its food value very high, and says that with meat and gravy it seemed to him superior to any starchy products in any temperate or tropical country. He also draws attention to the delicious puddings that can be made from it, especially if one adds plenty of sugar, milk, and butter! Perhaps the most important consideration, as Wallace also points out, is that a fair quality of flour can be manufactured from the dried fruit, available for a decent variety of bread and biscuits. I suppose there is no harm in adding that the bark, trunk, and gum of this tree is (or was) used by the natives of Polynesia for making all sorts of things—canoes, baskets, etc.

For me the chief attraction of this subject lies in the fact that we have sailed relatively near the scene of the greatest breadfruit story in all history. In 1772 William Bligh, then only 18 years of age, accompanied Captain Cook on his second expedition to the South Seas (1772–1774) as sailing master of the *Resolution*. The young man was greatly interested in the New World that was in this way opened up to him, and made a particular study of the Polynesian flora and fauna. When the expedition reached Otaheite (Tahiti) Bligh became acquainted with the wonderful breadfruit, and talked and wrote so much about it that his fellow officers nicknamed him "Breadfruit Bligh." At the end of 1787 he was sent to Polynesia in command of H. M. S. *Bounty* to gather breadfruit and other plants for cultivation in the West Indies. The expedition gained Otaheite in the spring of 1788. What happened shortly afterwards is told by Lieutenant Bligh in a small volume entitled "The Mutiny on Board *Bounty*:" "We sailed from Otaheite April 4, 1788, having on board 1,015 fine breadfruit plants, besides many other valuable fruits of that country which we had been collecting for three and twenty weeks, and which were in the highest state of perfection." Two weeks later he was seized in his cabin by the ship's master of arms and two others of the crew, pinioned and threatened with death if he made resistance. The crew also seized most of the other officers and gained control of the ship. The captain and 17 others were forced into the ship's longboat, 25 mutineers remaining on board. Lieutenant Bligh and the 17, touching at several islands by the way, finally reached Batavia and eventually England. The mutineers sailed the *Bounty* to Tahiti, where most of them elected to remain. Six of these were later apprehended, taken to England, placed on trial and three were executed. Meantime, in 1790, Fletcher Christian, the leader of the mutiny, 8 other Englishmen, 6 Polynesian men, and 12 Polynesian women embarked on board the *Bounty* and, after cruising about the Paumotus, took possession of Pitcairn, on the outskirts of that archipelago. This island is a mountainous, volcanic uplift area about 2 square miles, with several fertile valleys. Here this curious colony, having burned the *Bounty*, seems to have disappeared from the sight and knowledge of man. By the year 1800 all but one Englishman—Alexander Smith, who assumed the name of John Adams—had died. He appears to have been one of the few colonists to preserve a sense of responsibility, as he gained the respect of the natives and induced them to bring up their children in at least a semicivilized fashion. It was not until 1808 that the lost colony was discovered by an American vessel, the *Topaze*. Later other ships touched at Pitcairn and brought news of the

mutineers' descendants to the outside world. John Adams lived until 1829, and was succeeded by George Nobbs as chief magistrate. Through fear of drought, the whole colony were returned to Tahiti in 1830 on a British man-of-war, but they disliked the change, pined for their beloved Pitcairn, and were sent back in 1831.

The Pitcairners thereafter had an up-and-down career for another 25 years, when, in 1856, 60 married and 134 youngsters were again removed, this time to Norfolk Island. As time passed a number (40) returned to Pitcairn, so that in 1895 the population was about 170 souls. The Pitcairn people continue to speak the patois, mostly composed of the Tahitian of the original Polynesian women, that arose out of the mixed races that migrated in the days of the *Bounty*, and, although they show some of the signs of inbreeding consequent on their century of complete isolation, are, as a rule, intelligent and, for Polynesian half-breeds, an active and virile race.

The romantic story of the *Bounty* excited much interest all over the world, and attracted the attention of Lord Byron, then approaching the end of his tragic career. He further immortalized the mutineers in a poem—the last long one from his pen—entitled "The Island."

It is due to the memory of William Bligh, who rose to distinction and became an admiral in the British Navy, that the mutiny on his ship was no fault of his rule, but was the outcome of relations established between members of the crew and the women of the enchanted isle of Otaheite, an attraction that seems to have retained much of its force since the day that Cook sailed into the lagoon-harbor of Papeete.

Several friends have asked me whether the descriptions of tropical scenery and of tropical life—human, floral, and feral—that one reads as part of the voluminous literature of Polynesia, are not largely figments of the literary imagination. To this I answer: "Generally speaking, no; but not infrequently, yes." After all, the verdict depends upon the individual. Some there are who see only the beauty and the romance that is Oceania, while others, following an identical itinerary, see little that is satisfactory and learn only that Polynesian man in vile. Some are convinced that on these tropical islands "every prospect pleases" and that only the human element is objectionable; contrariwise, there are those who find all jungles and all atolls alike and that only the aboriginal or the "introduced" beach-comber is of interest. In all probability the truth lies midway. In any event I feel certain that the unprejudiced observer will always discover a continued charm in a country that is wholly new, remarkably varied as one travels from one island group to another, and full of natural history wonders. Possibly the following descriptions,

that I jotted down in my notebook from time to time, may appear to be sentimental exaggerations and worthy of being classed with the productions of South Sea "fakirs", but they were, at the time of observation at least, genuine impressions: One evening, half an hour before sunset, when E. and I were on the deck of our steamer then lying in the Papeete lagoon, she drew my attention to the fact that the two large islands, Tahiti and Moorea, the latter 20 miles distant, are admirably situated for displaying the wondrous magnificence of a tropical sunset. And so it proved on that occasion. Between the islands, in the roadstead, is a toy islet, with its quota of palms and other trees, that does duty as a quarantine station. Some time after the mountain peaks of Moorea obscured the setting sun, the weird and loftier crags of Tahiti were brilliantly lighted by solar streamers that seem to stretch across from the sister island. As the sun sank below the true horizon and the shades of tropical evening deepened into night all our surroundings—ocean, sky, mountains and islet—became the scene of fairy-like kaleidoscopic, color transformations that changed every minute, punctuated by the distant but regular roar of the breakers on the barrier reef and the cool "whiffs" of the delicious land breeze one may with confidence look for at nightfall in most of the southern Tropics. We agreed that we had seen as lovely sunsets elsewhere, but none with such a remarkable environment.

Here is another note: Last August (at the end of the southern winter) I wished to study (in their wild state) the beautiful fruit pigeons of Fiji, and for that purpose took a native cutter bound for Kandavu, a mountainous, volcanic island, the most southerly of the Viti group and in the fifties an American whaling station of sorts.

Kandavu is about 27 miles long, four wide, and lies 60 miles from Viti Levu. This charming volcanic uplift is practically shut off from the world. On it are only four or five white planters who have no telephones or telegraph stations, no roads and no post offices worth talking about. There is no communication with the other islands except by occasional—very occasional—Fijian craft. Now and then a native journeys from one village to another over ill-kept jungle trails, almost impassable to Europeans. My artist companion—a dextrous painter of animal life—and I put up at the hospitable home of Mr. and Mrs. M., educated English people and the only Europeans on the western end of the island. Their house was built on an eminence, itself surrounded by verdure-clad hills, except toward the northwest, where an opening in the hilly amphitheater furnished a view of a beautiful bay. In its turn the bay was protected and cut off from the ocean by a coral reef that continuously threw up a succession of many-sounding breakers whose outlines were plainly visible by contrast with the blue waters of the bay. Trees of every tropical variety, both wild and cultivated, covered the bowl

of this ancient crater, while birds of many kinds—parrots, parakeets, sun birds, Fiji "robins," honeyeaters, fantails, pigeons, doves, hawks—gave additional color to the landscape and lent musical notes to the loud babbling of a brook that ran past the house on its way to the ocean. As if to perfect this Fijian paradise, the white blossoms of several frangipane trees blew their strong fragrance through our rooms day and night.

Unless I was too fatigued from tramping over hill and dale through the rather difficult jungle, I rose an hour before daybreak that I might refresh myself by drinking in the glories of the starlight sky, much of which I had seen in 1923 for the first time. Standing well within the bowl of the long-inactive crater, the oncoming dawn was an entirely new experience. As the eastern heavens lightened, the shadows of the valley beneath appeared to deepen, but at last the honeyeaters began their earliest notes, and with these matin songs the outlines of cocoa palms, breadfruit trees, mangoes, bananas, and other plants assumed individuality until over the edges of the green-rimmed hills streamed the first rays of the morning sun. They fell upon the opposite slopes, bringing with them a perfumed atmosphere redolent of the ever-flowering trees, shrubs, and vines that clothed the green hillsides to their very tops. Of course, the wonders of rosy-fingered dawn have been celebrated in song, verse, and prose many times these thousand years, but my contention is that when dark night rolls back into the ocean around wild Kandavu it does so in a fashion all its own. Other sunrises may be as impressive and as beautiful, but when viewed from the Korolevu crater they have charms inherent in their environment—charms due to just those every-day surroundings that are tropical life.

What is true of the scenery, the flora, the fauna, and the meteorology of Polynesia is also true of its human element. I am quite sure that while writers of Oceanic fiction often draw upon their boundless stories of pasteboard heroes and heroines for tales that are largely products of an excited imagination, there are many lives at this moment being lived on the islands of the South Seas that properly belong either to a century in advance or several hundred years behind our own times. I wish I had the space and the permission to relate the intimate histories of some waifs and strays as well as of some idealists whose acquaintance I made during my sojourn in central Polynesia. The objection of publishing the recitals would be the raising of doubts as to their reality, whether such individuals live within the realms of fact or fiction. So, I would say, nothing any South Sea romancer may write is likely to transcend the limits of the possible so long as he deals with human beings.

Of course we were much interested in and always on the watch for a sight of an albatross. The Pacific coast is occasionally the resort of four humble members of the family, but not of "the bird that made the wind to blow." He, the wandering albatross (*Diomedea exulans*), is almost pure white, the back showing narrow, transverse, wavy dark lines, the quills of the wing feathers being black. Some writers probably exaggerate this bird's spread of wing; Ridgway says that it is about 11 feet (from 125 to 130 inches). The bill is yellow, becoming orange at the base.

Many are the descriptions of the wonderful powers of flight shown by this denizen of the southern ocean. For instance, Greenbie is moved to use the following language: "But chill and melancholy as was that southern sea, there hovered over it a creature whose call upon one's interest was more than compensating. Swooping with giant wings in careless ease, the albatrosses follow us day in and day out. Always on the wing, awake or asleep, in sunshine or in storm, the air his home as water is to fish, and earth to mammal. Even the ship was no lure to him by way of support. He followed it, accepted whatever was thrown him from it, but as for dependence upon it—no such weakness. Swift, huge, glorious, unconsciously majestic, he is indeed a bird of good omen. How he floats with never a sign of effort! How he glides atop the waves, skims them, yet is never reached by their flame-like leapings; simulates their motion without the exhaustion into which they sink incessantly. He does not gorge himself as does the sea gull, nor is he ever heard to screech that selfish, hungry, insatiable screech. Silent, sadly voiceless, rhythmic, symbolic without being restrained by pride of art, he exemplifies right living. He is our link between shores, the one dream of reality on an ocean of opiate loveliness wherein there is little of earth's confusion and pain."

Major Le Souef reports (*Emu*, p. 53, 1922) that during a recent trip to England from Sydney *Diomedea exulans* was much in evidence, and was a faithful follower of the ship. As soon, however, as the outside temperature rose above 70 degrees F. at 4 o'clock p. m. the wandering albatross invariably left the track of the ship and flew southward in search of cooler weather. In other words, Le Souef thinks that temperature is an important factor in determining the range of this bird. He calculated the flight of these albatrosses at from 20 to 40 miles an hour. He also noticed that the Atlantic adults have more brown in their plumage than those he saw in the Indian Ocean, the latter presenting beautiful, pure white wings whose silvery tones are heightened by their black tips. I have also noticed the effect of temperature on range (and have reported it in the same journal) relative to the New Zealand

albatross (*Diomedea regia*), that I regard as the most beautiful, although it is not the largest of the albatrosses.

Another bird I saw in the South Seas was *Phaethon rubricaudus*, the red-tailed Tropic bird, largest of the genus. He derives his name from the bright crimson-red of his elongated and very attenuated rectrices. His mandibles are also red, and, when full grown, his white plumage is tinted a deep roseate hue—altogether a beautiful bird. I wrote from South America of my experiences with the yellow-billed Tropic bird (*P. flavirostris*) (called "long-tails" in Bermuda), and I was on tiptoe to see his relative flying about the southern ocean. Moreover, I hoped to see a young bird, with the black, arrow-head markings on its back. I also wondered whether those barbarians who shoot this lovely creature for the bright red feathers of his tail (let us not forget those *participites criminis* who wear them) are still at their nefarious work.

Stevenson, one of the most careful observers, several times speaks of the southern Tropic bird. In one instance he makes, however, a mistake which is quite pardonable, and which has been made by others, in supposing that there is but one, and not two, long feathers in the bird's tail—an error due to the fact that in molting the feathers are renewed irregularly and, in consequence, one feather frequently projects much beyond its fellow and gives the appearance of a single plume. The paragraph referred to is from "The Ebb Tide," page 130: "* * * around and about the schooner a Tropic bird, white as a snowflake, hung and circled, and displayed, as it turned, the long vermilion feather in its tail."

While climbing the long but beautifully shaded trail that zigzags the slopes of Mount Vaea on a pilgrimage to Stevenson's tomb we saw, sailing up and down the valley beneath us, a splendid red tail, flying directly over Vailima. Perhaps he was a descendant of one of the poet's birds.

Mr. D. McDonald, chief officer of the steamship *Tahiti*, who for years has studied the oceanic life of *Phaethon rubricaudus*, tells me that these birds come on board practically always at night; and when they do so it is not (or rarely) because of exhaustion or because they are blown aboard, but because they are attracted by one or other of the ship's lights. They generally fly directly at the lantern, and are often stunned by the impact. They then fall onto the deck and, owing partly to the confusion produced by the blow, are unable to fly off again. Mr. McDonald does not think that the injury is alone responsible for their helplessness (that generally leads to their capture); in addition, they seem unable to get a grip on the smooth, often slippery, deck without which they can not acquire the headway necessary for upward flight. Nor does he believe that, as

may obtain in the case of insects, they are lured by the illuminated lantern as such, for no sea bird would deliberately smash into an object, especially one so visible as a night light, unless he were deceived as to its solidarity. No; the fact is the bird thinks, so avers Mr. McDonald, that the lighted area of the lantern and its immediate surroundings constitutes an exit into daylight beyond. We all know that a bird in a darkened barn or other inclosure easily discovers and flies through a hole or other opening that gives on the daylight. It is not that he is attracted by the light area of the exit, but he visualizes and seeks, by means of the opening, the free air of heaven beyond. Thus it is with certain birds at sea; they expect to fly through the light and not at it. The dark or dimly-lighted canopy of the night represents to them a sort of antechamber of the day; the light at the masthead is one of, it may be, many openings through which the great, diurnal outdoors may be reached. *Pensieri vani* for the bird, you may say, but not more vain, is it, than the beliefs about the causes of daylight and darkness that were devoutly held by educated and polished races of mankind not so many years ago. I can not recollect that Gaetke or any other observer of lighthouse tragedies has explained them in this fashion, but the chief officer's theory sounds feasible to me. At any rate I give it for what it may be worth.

Then there is that other question in comparative psychology to answer: Is there, in this search for light, evidence of a superior or of an inferior avian intelligence? Because we know that there are sea birds that follow or fly about ships who are not attracted by lights in this manner—gulls and albatrosses, for example—probably because these are not nocturnal wanderers, except on moonlight nights.

Among the many Australasian avifauna that I was set upon seeing in their native surroundings if possible, was the *lyre bird*—familiar to everyone who has read about the curiosities of the "Lonely Continent." It is only the full-grown male that has the wonderful tail—composed of 16 feathers, the two outer curved to form that remarkable lyre-shaped ornament that distinguishes it from any other species. The best known and the most highly ornamented species (*Menura superba*) is a native of New South Wales and southern Queensland. It is about as large as a small turkey. The possession of this beautiful and wondrous tail is not, however, the only unusual quality that distinguishes this peculiar bird; he is a fine singer and peerless mimic. Just how he came to be included in the *Pseudoscines*, or false song birds, is difficult to understand, considering that his musical ability has been known and recognized from early Australian days. Another accomplish-

ment is his well-developed powers of mimicry. This additional attainment was especially insisted upon by an Australian ornithologist, guest of the British Ornithologists' Club, when I was in London last summer. He claimed that the male Menura is unequaled in this respect; and we know that many other observers have recorded instances of this curious trait. One gentleman had a lyre bird as a pet around his farm in Australia for a great many years. "There was nothing he could not imitate. The following are a few of his mimicries: The noise of a horse and dray moving slowly, with the play of the wheels in the axle boxes, chains rattling, etc.; an occasional 'Gee up, Bess'; the sound of a violin, piano, cornet, crosscut saw, and so on. All the more frequent noises heard about the farm the bird learned to perfection, such as a pig being killed, a dog howling, child crying, cries of a flock of parrots, jackass laughing, and many calls of small birds."

It was a rare privilege for me to see in company with Doctor Le Souef, director of the Sydney Zoo, and a number of other distinguished ornithologists, three of these remarkable birds in the National Park, exhibiting the best of their mimetic and other stunts. You can imagine how lucky I was when Gould relates that he was a year in Australia without seeing one, although he heard many.

I never see the name Norfolk Island (past which we sailed) without recalling the image of a transplanted, but perfect example of its so-called pine—the beautiful *Araucaria excelsa*—60 feet high, delicate green, and straight as a die, that one may at any time see near the Hotel del Coronado. This symmetrical beauty performs the useful function each holiday season of a live, outdoor Christmas tree. Bedight with colored electric lights from its spreading base to its conical top, it is easily the observed of all observers, and both day and night is a most attractive object. As if further to fit the purpose for which it is borrowed, the extreme apex of the tree terminates in a sort of Maltese cross, and forms a convenient and appropriate anchorage for the traditional Star of Bethlehem. It was Captain Cook who discovered and christened the island—after the ducal family of the same name. He says of the tree: "The chief produce is a sort of spruce pine, which grows in abundance and to a great size, many of the trees being as thick, breast high, as two men could fathom, and exceeding straight and tall. It resembles the Quebec pine"—and we must not forget that for several years the captain cultivated the acquaintance of Lower Canadian timber.

There is, or rather was, a beautiful Norfolk Island parrot (*Nestor norfolcensis*) of which only one bird skin remains, and a single drawing to perpetuate its memory. Thus vanishing is many another species and race of Polynesian fauna.

It was reminiscent of home to find the Pacific godwit (*Limosa lapponica baueri*) in north New Zealand. I am also reminded that there is at least one compensation in visiting Australasia during the "off" season for birds; one sees some old friends in the shape of migrants who for reasons of their own fly across thousands of miles of ocean to spend the winter in that delectable land. It might be supposed that all birds that insist on breeding in countries with a snowy season would, after a dozen or two generations of experience, seek the nearest warm or moderate winter climate furnishing sufficient food. However, as every budding ornithologist knows, some do not, and perhaps not even the most erudite and experienced student of bird behavior knows always why. In any event, the attempted solution of this problem has added much literature to distributional ornithology, and it is still coming in. Speaking again of godwit migration, at the northern extremity of North Island, New Zealand, is the Bay of Spirits—so called from the Maori belief that the souls of the dead take their flight into the other world from this locality. It is an uninhabited lonely coast, the last stepping-off place, as it were, and would appear to be appropriate for the purpose assigned to it by a barbaric but imaginative race. There is, however, another reason, probably the reason, for this tradition: also at the northern tip of long and narrow New Zealand is the rocky plateau where the godwits assemble in thousands for their annual return to Siberia. It must be a wonderful and awe-inspiring sight. Even the matter-of-fact Buller (Manual, p. 56) is moved to these words: "Rising from the beach in a long line and much clamor, they form into a broad semicircle and, mounting high in the air, generally take a course due north; sometimes they rise in a confused manner; and, after circling about at a considerable height, return to the beach to reform, as it were, their ranks, and then make a fresh start on their distant journey. The departure from any fixed locality usually begins on almost the exact date year after year; and for a week or 10 days after the migration has commenced fresh parties are constantly on the wing, the flight generally taking place about sunset, and sometimes after dark." Does it not seem likely that a people of our own Aryan stock might easily translate this truly wonder-working episode into the belief, so firmly held by most aboriginals, of a happy hunting ground to which journey the spirits of the dead when this fitful fever called life has run its course?

Not only is the parson bird (*Prosthemadera novae-zealandiae*) or *tui*, as he is called by the Maoris, one of the most striking but he is also among the most interesting of the New Zealand avifauna. Imagine a bird about the size and general appearance of our common crow, generally of a metallic bluish or greenish black, the upper

part of his neck wearing a collar of gray, threadlike plumes with an outward curve. There is also a prominent white spot near each shoulder, and from the throat of the adult bird hang two tufts of white, curly feathers that look for all the world like the white bands of an ecclesiastic. Moreover this prominent "choker" can readily be seen as the bird flies about from tree to tree; and it is impossible to mistake him for any other species. In the Auckland district he is most likely to be found in the "ranges," so, one fine day, accompanied by Mr. R. A. Falla, (R. A. O. U.) of Devonport, we made a field trip to these hills, where we saw a number of tuis, beautiful pied fantails (*Rhipidura flabellifera*), silver eyes (*Zosterops caerulescens*), and many another beauty in the tree ferns, shrubs and other foliage; while, flying high in the air, was a hawk (probably *Nesierax australis*), a colony of parrots—very likely of the introduced Rosella parakeet—and a number of others. We took our luncheon on the slope of a gulley whose sides and bottom were covered with a wonderful array of tree ferns, while our tablecloth was spread on a bed of New Zealand bracken of sufficient thickness to raise it well above the level of our feet. Here, while we discussed our simple meal with an outdoor appetite, Falla, an experienced ornithologist, gave the tui call and before long there was an answer from the depths of the forest. Then two birds came within plain sight, and after looking us over approached so that with our glasses we could study them in every detail, even to the whitish line that separates the nuchal feathers and the white spots on the wings.

Greenbie (The Pacific Triangle—1921) says of the parson bird: "No sound of bird in any of the many countries I have been to has ever filled me with greater rapture than did this. There are thousands of skylarks in New Zealand, brought from England, but had Shelley heard the tui he might have written an ode more beautiful even than that to the "blithe spirit" he has immortalized."

Buller (Manual, p. 10) remarks that "Owing to its excellent powers of mimicry, and the facility of rearing it in confinement, it is a favorite cage bird, both with the natives and with the colonists. Although of very delicate constitution, it has been known to live in confinement for upward of ten years. More frequently, however, it becomes the subject, after the first year, to convulsive fits, under which it ultimately succumbs. Cleanliness, a well-regulated diet, and protection from extremes of temperature are the proper safeguards. Naturally of a sprightly disposition, it is cheerful and playful in captivity, incessantly flitting about in its cage and mimicking every sound within hearing. It will learn to articulate sentences of several words with clearness and to imitate the barking of a dog to perfection. The Maoris appreciated the mocking powers of this bird and devoted much time and patience to its instruction."

Mr. Louis Griffin, of the Auckland Museum, tells me that he once possessed a tui, of whom he became very fond. This interesting animal not only reproduced many of the sounds he heard but repeated a number of short sentences appropriate to various occasions. He took a bath twice a day and on these occasions invariably dipped his head and white choker in the water as a first ablution. He then carefully preened himself, drying and arranging his ecclesiastic insignia, afterwards taking a plunge that involved his whole body. Then, when the bath was fully concluded, he would fly to his master's hand, perch himself on it, and repeat a portion of his conversational repertoire. Twice he escaped from the house and once he returned. On the second occasion, although he remained about the premises for a day or two and answered Mr. Griffin's call, it was the "time of the spring running," and he never came back.

The pied fantail must attract the pleased attention of every visitor to New Zealand, as it is to be seen almost everywhere on both islands. It and its Australian cousin are among the most attractive of the small flycatchers. They seem to be constantly on the wing, performing (with tail widespread) the most varied and fantastic evolutions in their pursuit of flies and gnats invisible to our dull eyes; in fact, they hold the blue ribbon for artistic gymnastics. The New Zealand bird is *facile princeps* flycatcher of the world series.

There are many reasons why the word "gull," used as a synonym of "dupe" or "fool," is a misnomer. It is difficult to understand how this misapplication came about. I have made a study of gulls for many years, and rank them high among the intelligent orders. In fact I regard them not only as types of avian grace and beauty, but as examples of advanced intelligence; and, in that respect I agree cordially with the views of the Finleys, who, within the past year, have written a paper (see The Atlantic Monthly) on this self-same subject. In my opinion and experience, gulls are by no means "gullible." Last summer we were staying for a short time at the Atlantic Hotel at Newquay, England; and, while at breakfast, we noticed a full-grown herring gull fly from the seashore, a few hundreds yards away, and light on the terrace close by the dining room. He was followed shortly by others and by still others until there were, perhaps fifty waiting about. My wonder at this strange phenomenon was soon satisfied; they, too, had come for breakfast. In a few minutes one of the hotel people arrived with a can of "leftovers," and it certainly was a sight to watch the array of heads, wings, feet, and bodies that forthwith hid, as by a dense cloud, the scattered piles of food. It was especially interesting to watch the late arrivals, fearful of being excluded from the feast. They literally threw themselves, screaming, into the struggling mass of white, grey, and black feathers. As the birds were perfectly

tame and unafraid, there was a fair field for all, and I was sure no gull flew away without some scrap to satisfy appetite. I was informed that the bird feeding was held every morning at the same hour, and that the hotel guests regarded the ceremony as one of the attractions of the place.

More recently, in California, I began a similar practice, and soon had an expectant colony to feed on the sandy shore near our hotel. Quite a respectable collection of western and other gulls gathered about 9.30 each morning, and when I appeared with a bag of "seconds," some twenty or thirty birds rose to meet me and circled about my head until I arrived at the feeding ground. Then we had a sort of athletic "meet."

One of the first contests was staged by throwing into their midst a large, hard, breakfast roll. This edible was forthwith seized by a gull, who, unable to swallow it, at once made off, followed by half a dozen others in search of a place of safety. The pursued and the pursuers flew a fine aerial course; the bird, with its mouth full of bread, often rising high in air, swooped, dodged, and doubled. Finally, he broke away in a much wider circle than usual, intent on tiring out his pursuers. However, all these maneuvers ended the same way, in the dropping of the roll, to be caught up by a second gull and the continuation of the flight and pursuit. Eventually some experienced bird would grasp the breakfast dainty and fly down the coast for half a mile or so until his pursuers abandoned the chase. But I noticed on these occasions that the successful bird did not return; his time for the subsequent half hour was occupied in soaking the hard bread preparatory to tearing it in pieces small enough for deglutition. Occasionally we substituted for the roll a hard-boiled egg. This much-prized article was immediately caught up and passed from one gull to another by vigorous action until it was either smashed by falling on a rock or until some bird with an abnormally wide gullet managed to swallow it. To accomplish this latter feat while being chased at full speed seemed no easy task; it is possible that it was sometimes accomplished only by crushing the egg between the mandibles of a particularly powerful gull.

After a time we came to recognize individuals of the flock. One fat old bird we christened "Squawker." As soon as one of us appeared in sight this gull opened his mouth wide, emitted a series of loud, hoarse cries, and darting at the other gulls in his immediate vicinity proceeded to run amuck through the whole flock. This strategem, intended, one may suppose, to intimidate the other feeders, he repeated every two or three minutes while the feast lasted. He rarely got anything to eat, however, unless food were thrown directly to him; he was so busily engaged in squawking, air-

ing his importance, and in assaulting the neighbors that the other gulls, meantime, had all the advantage and ate all the provender.

Of the fifty or more species of gulls found all over the world, at least thirty inhabit the Americas. It is difficult to explain their complete absence from the immense ocean area between the South American Continent and Australasia. It seemed as if we had missed something when, after the crowds of gulls in San Francisco Harbor and along the Pacific coast, we failed to see a single one during the long journey to New Zealand. I presume little of the food the birds crave is available in the lagoons and atolls of Polynesia.

Although I have studied these birds in many lands, I have never seen any of them catch fish after the manner of their cousins, the terns. On one occasion I thought I saw a western gull light on the water and pull out a fish, but of this I am by no means certain; the bird gave me little opportunity for investigation, as he swallowed his catch at once, without taking wing. Moreover, the prey may have been a dead fish floating on or near the surface. I was, of course, fairly well acquainted with the hawking habit of our laughing gull (*Larus atricilla*), as well as the Franklin and other species, and have seen individuals of several of these hunting and catching insects and even field mice, swooping after them almost with the agility of sparrow hawks. In view of this lack of opportunity, I was much interested in the account furnished by a writer in the contributor's column of a recent *Atlantic* of "gulls" (probably species of booby) in South America that, unlike their northern relatives, dive to a considerable depth for fish: "These birds are very similar to their cousins of the north; they are, though, less well groomed, and do not look as sleek and nice as their northern neighbors. The only noticeable difference is in the shape of the wing, which has a decided break, and not the even beautiful curve of the wing that the northern sea gull has. From my home in Valparaiso I have watched these birds dive, and sometimes from a height of a hundred feet. It is a peculiar thing that they do this in flocks rather than singly. A most remarkable sight it is to watch—to see a hundred or more birds turn, as if by one accord, close their wings and dive in after the fish. A beautiful sight it is, too, to see a flock of sea gulls serenely circling above the waters dive, to catch for a moment the flash of the white feathers of their upturned wings in the sunlight, to see them strike the water, and again to see them bob up one by one. Of note is it that almost never did I see one return unrewarded."

Did you ever notice a colony of gulls sitting quietly in the open? If there is little or no wind, and the day is bright, they stand or lie, either in a long line or in closer formation, facing the sun. And, by the way, what a pretty sight—these smooth, well-groomed, statuesque,

half-white bodies, bathed in sunshine and artistically posed, as if for our pleasure and admiration. If there is little sun and no wind, they face in various directions; there is no uniformity in their ranks. If there is a high wind, however, they turn toward the quarter whence it blows, probably to prevent ruffling of their feathers and cooling of the skin surface.

There must be a considerable difference between the acuity of vision in gulls. I am not prepared at the moment to discuss this matter, but I have never been able to repeat an experiment I made some years ago on the species—*L. ridibundus*, I think—that is abundant on the Lake of Geneva. During excursions to Ouchy and other resorts along the lake shore it was my habit to carry with me a bag of grapes with which to feed the gulls. Parenthetically, all the gulls whose acquaintance I have made are very fond of grapes. I soon found that they would hawk the fruit when thrown one by one into the air. I then tried to find how small an object could be seen and caught in midair by these birds—to discover that the smallest grape in my collection when tossed into the air was retrieved before it reached the water. I have not been able to repeat that little experiment with any of our western or California gulls.

Referring once more to the black-headed gulls whose acquaintance I cultivated at Ouchy nearly 20 years ago, they must not be mistaken for our black-headed or laughing gull (*L. atricilla*). Both are quite common birds within their respective ranges, but the Swiss species is much smaller and its plumage more charged with black than the American variety. Perhaps I was among the first of those to whom my former teacher in the London Hospital, Sir Frederick Treves, refers in his charming book, "The Lake of Geneva," as visitors "who have so persistently fed these (black-headed) gulls that they are demoralized, and will shortly become, like the pigeons of Venice, a company of tourist-supported idlers."

As every mother knows, the color of her infant's eyes undergoes changes, more or less marked, during the first year or two after birth; but these alterations are negligible when compared with the eyes of some birds. For example, the very pretty, and often very tame, little red-billed gull (in New Zealand, the mackerel gull) or *Larus scopulinus*, is born with dark-brown, almost black eyes, and yet by the time it is a year old they have changed almost to a pure white. A similar alteration is noticeable in the iridic coloration of the larger but equally beautiful southern black-backed gull (*Larus dominicanus*), that ranges the whole Southern Hemisphere. Both these birds are easily domesticated; they act as valuable scavengers, and are devourers of caterpillars and other insect pests. It is interesting to see them about Australasian harbors and fields, doing their useful work, unafraid of man.

The vulgar name "bell bird" is given to many quite different species in various parts of the world, but in every instance it is applied because of the resemblance of the bird's call note to the tolling of a bell. I have already spoken about the representative of these remarkable animals found in the northern parts of South America and I was naturally on the look out for their Australasian congeners. The New Zealand bird is a honey sucker—*Anthornis melanura*—alas, fast becoming extinct. It was this remarkable bird that attracted the attention of Captain Cook. On his second voyage while his ship was lying in Queen Charlotte's Sound, the crew heard bird notes "like small bells most exquisitely tuned." On the Australian Continent two species, one also a honey sucker, *Manorhina melanophrys*, and another, a shrike-like bird, are called bell birds. Of the former Buller says, "Its notes, though simple, are varied and sweetly chimed, and as the bird is of social habits, the morning anthem, in which scores of the sylvan choristers perform together, is a concert of eccentric parts, producing a wild but pleasing melody. When alarmed or excited they utter a strain of notes which I can compare only to the sound produced by a policeman's rattle quickly revolved. This cry, or the bird catcher's imitation of it, never fails to attract to the spot all the bell birds within hearing."

One clear day I visited Quarantine Island, Auckland Harbor, as the guest of the chief engineer of the harbor board, Mr. W. H. Hamer, himself a keen and well-informed naturalist. We found there many birds that I had no expectation of seeing, among them many bell birds. The ordinary song of the New Zealand species resembles that of the parson bird, and while we sat listening to what seemed to me to be a sustained song a discussion took place among the ornithologists present as to whether the avian music we were hearing was that of a tui or not. A portion of the song certainly recalls the notes of a bell, and it has a metallic ring about it that serves to distinguish the call notes of the New Zealand bell bird from the sustained and softer song of the tui, but neither of them in any respect suggests the solemn tolling of the South American bird, with his single though prolonged note. The Australian chorus of performers reminds one of a chime, or of several mingled chimes, of small, silver-tongued bells, while the New Zealand performers make one think of the rendering of a musical number by minor brass instruments. *Anthornis melanura* is smaller than our robin (male, length, 7.5 inches; female, 6.4 inches), color generally light yellowish green in the case of the male bird, but this must be modified by stating that the head is steel-colored, while the tail is brownish black. The female is browner and less conspicuous, but both sexes are equally good singers.

To distinguish the two Australian varieties, *Manorhina melanophrys* is called bell minor. Unlike the nearly pure white Guiana bell bird, *Chasmorynchus niveus* (of a different family), it is of a beautiful golden green plumage, except the wings and tail, which are dark brown. The eyes are dark brown, the legs and feet a light orange. In the case of this bird the notes seemed to me a faint tinkle, like the sound of distant sheep bells. I heard a flock of 50 of these remarkable birds give a charming concert about a little lake 20 miles from Melbourne.

Mr. H. R. Haeusler (Emu, vol. 22, January, 1923) has had unusual oppportunities to study the kiwi (*Apteryx mantelli*), and finds his vision, during the daytime at least, to be very poor. Chopped meat, worms, etc., placed in front of these wingless, nocturnal, New Zealand birds were apparently not perceived at all until they had been "felt" by the supersensitive terminals of their long mandibles. Both these articles of food, as well as the entrances to worm holes. were located by "tapping" about with their closed bills. Mr. Haeusler is convinced that in gathering food and for most other purposes involving localization, neither sight nor smell is to any extent relied upon; the bird locates objects mainly, and in many instances entirely, by touch. Having found the entrance to a worm hole, the kiwi enlarges it to a funnel-shaped cavity and, after grasping the prey, pulls steadily upon the worm until the latter is tired out, looses its hold, and is drawn to the surface. If alarmed, the Apteryx "plays possum," and with bill stuck into the ground keeps as still as death, its peculiar coloring making it difficult to see the bird as long as it does not move—the old story of protective coloration. From my own observations of this remarkable species I am convinced that its night vision is much better than its diurnal, as indicated by its liveliness at night and its pronounced orange-red fundus, which closely resembles that of the owls and other nocturnal species. I had several opportunities of observing these birds and of examining their eyes in the London Zoo.

Many writers tell us all about the Polynesian hermit crab, and some of them speak as if he were peculiar to Oceania. As is well known, this comic and attractive animal is widely distributed over the earth's surface under the forbidding family names of *Paguridae* and *Parapaguridae;* indeed, more than one (small) species is rather common along the Atlantic coast. The following is what one of our most reliable authors tells us about this creature: "The hermit crab is the best bait for fishing in the waters of the South Sea islands. There must be several varieties. I have counted three already: The ordinary, small brown one called *kakara*, the huge red one found in deep water, and the black, hairy kind, whose pounded-up body is mixed with grated coconut to extract the oil. This latter is called

Unga; in the old days the lowest class of Rarotonga society was known by the same name, meaning, i. e., that all their property could be carried on their backs. The common variety is a good deal like the robber crab in habits; the natives go so far as to say that it is the same animal. The size of the *kakara* can be judged by the size of his shell, which may be as small as a thimble or as large as an orange. His soft and muscular body curls into the spiral of the shell and is securely anchored by a twist of the tail. The interior end reminds one of a tiny lobster; the same stalk eyes, same legs, and strong claws. Maugre his name, he is gregarious."

One day I was patiently and vainly waiting to catch a glimpse of an exasperating lot of wild jungle fowl (near relatives of the ancestors of our farmyard rooster and hen) that I had heard cackling and crowing in the mountain forest of Beqa (or Mbenga, as the Admiralty charts prefer to spell it, so the stranger may correctly pronounce the name of this geographically important island) and had come to rest on a trail about a thousand feet above and overlooking the ocean. Beneath me a little native village, whose chief was our host, lay scattered along a coral beach for half a mile. Barely visible over the edge of the cliff was the chief's guest house and a small weir in which was imprisoned a huge turtle for his chiefly table; turtle is taboo for any Fijian below the rank of *Buli*. Until the chief had, a few days previously, sent four as a present to the quadrennial conference of chiefs, the watery inclosure was pretty well filled with these ugly but toothsome chelonians. Beyond lay the bay, and basking in the sunshine on three native boats sprawled a dozen or more sailors, among them two or three Solomon Islanders assisting the Fijians in a task in which the latter specialized, the South Seas form of the *dolce far niente*. The day was so beautiful that I forgot all about the "wild barnyard" I had come so far to see, and gave myself up to imitating and sympathizing with the Polynesians in and on the water below me. I happened to look at the partially covered path a few yards ahead of me and became aware dimly that the square of earth was moving ever so slowly down hill. A clearer view of this spot revealed a well-packed array of shellfish of all sizes, big, little, and smallest, the last less than half an inch, the first 4 or 5 inches across. Evidently a number of gastropod families were on the move and headed down the trail. This guess proved correct so far as the exterior shell was concerned, but the live interior turned out to be an equal number of crustaceans—a large colony of hermit crabs on the march. With a stick I touched several heads to see them withdrawn within the concha, and marveled at the excellent choice these creatures had made of properly sized shells, how well they fitted, how nicely concealed was each interloping crab in his armored retreat, secure from outside

enemies. It is probable that, in some instances at least, the crab first attacks and then eats the mollusk whose shell he afterwards appropriates.

Engaged in these investigations, I did not notice, partly concealed as he was by the pathside vegetation, a figure that made me laugh and continue to laugh. As this, the largest of the crabs, crawled out of the herbage into the cleared trail I saw that he was not garbed in appropriate dress. Instead of the outworn shell affected by all his companions, he was girt about by a segment of coconut that covered only part of his body, much as the conventional, unclothed tramp is pictured as veiling his nakedness by means of a flour barrel. Indeed, the old crab looked like a disreputable "drunk" as he staggered along in his ancient, broken, and weather-beaten nut shell. It was, of course, no fault of his that the sea gastropods on Beqa did not grow large enough to furnish shelter and to meet the exigencies of adult fashion in dress. However, he kept step with the moving ranks, the ill-clad hermit forming the rear guard, staggering along until he was the only crab in sight. Then with a final wave of his antennæ, as if in jaunty adieu, he rolled his shabby old shell into the leafy débris of the forest and disappeared from my sight.

In the harbor of Apia lay H. M. S. *Laburnum* of the New Zealand Navy, and just before we sailed for Tonga there was transferred to us from her a more or less tame, immature, female *Fregata aquila.* The bird was destined to the Auckland Zoo, and the story ran that some officer on the warship had bought it, a captive of some months standing, from a native of Hull Island in the Phoenix group. He, or rather, if my guess should turn out to be correct, she, soon became an object of considerable interest to the passengers. From her comparatively lofty perch on the gunwale of the lifeboat that was set apart as her living room she gazed with unconcern at the admiring crowd below. Many times a day she scrambled from the depths of the lifeboat to preen herself, especially after a shower, and to dry and air her immense wings in the tropical sunshine. The ignominious part of the performance was that it was necessary to tie the bird by one leg to the thwarts, and the restraining rope embarrassed her efforts to perch and spread her wings, owing to her weak legs and her immense wings; and it certainly was a beautiful sight to see her magnificent wing spread of not less than 6 feet. The officer who had the new arrival in charge certainly did all he could to make Fregata comfortable, provided her with a box into which she retired whenever she wished, gave her all the fish she could eat and all the water she could drink. In deference to the positive statements of a passenger, who proclaimed himself an authority on man-of-war birds, she was provided daily with a can of sea water, that being the proper drink for this ocean-going fowl. As this dictum sounded

much like the ancient belief that parrots should never be given water to drink—an obsession that has caused so much misery in the psittacine world—I determined to investigate it. And sooner than I expected the opportunity arrived, because shortly we had a tropical downpour that thoroughly drenched the bird and her surroundings. It was good to watch the Fregata for the half hour the storm lasted. She certainly enjoyed her bath, spreading wide her long, pointed pinions to allow the cool douche to reach the hot skin of her sides and underparts. Now and then she would flap her wings to shake off superfluous water, but she did not retire to her box or make any other effort to avoid a full bath. But the way in which that bird drank rain water! For at least 10 minutes she did nothing else—opening wide a capacious mouth to catch the drops that not only fell directly into the orifice but that ran down the sides of the mandibles. First she opened her beak, then pointed it aloft, as if trying to drink in as much of the falling water as possible, and when she had secured all her throat would hold made evident swallowing movements. There could be no doubt that for this bird at least soft water was a desirable beverage; and I can readily believe that in the upper air, where her folks spend most of their time, this performance may go on without the necessity of resting on the waves or of roosting on dry land. I never saw the man-o'-war preen herself in the sense that so many other birds are wont to do. I have an idea that the very large birds do not, as a rule, indulge in that method of feather cleansing. I have noticed the large birds of prey, herons anhingas, etc., proceed, as our Fregata did, that is, shake their wings and body and then sit in the sun and dry themselves after a torrential shower bath or plunge. After this thorough wetting Fregata seemed content to hold her wings semiextended, to flap them now and then, and to shake herself, dog-like, every two or three minutes, and then to let the warm sun do the rest.

Every day I climbed to the bird's retreat invariably to find that she appeared to have made herself entirely at home and was not at all alarmed by the approach of strangers. The most hostile act she was guilty of was to make a sort of grunting noise and open her beak at the intruder. As she was taken from the nest (probably, that is) and tamed by association with a native family, the chances of becoming reconciled to captivity in a public zoo are good; yet these birds make very poor cage birds, generally dying of homesickness, or the infections induced thereby, within a short time. The feathered animal whose home is the illimitable blue sky soon sickens even of the largest flight aviary and, though he may be only a robber and live by piracy, yet he prefers death to loss of freedom.

There are few or no monkeys (or for that matter few other mammals) in eastern Polynesia. Perhaps the earlier voyagers from the mainland had not learned to carry them as pets, like many other native tribes, on their long sea excursions, or they did not survive the exposure incident to canoe life. In any event, it is not until one reaches islands relatively near the Asiatic coast—Borneo, New Guinea, Java, the Celebes—that simian life becomes abundant. It is quite otherwise with the West Indies, where even to the present day monkeys are to be seen in some of the islands.

As every ichthyologist knows, not all the so-called flying fishes belong to the same genus or even to the same family. In one or other of their many forms they are found all over the oceanic world. The true flying fish—perhaps we say true because it is the commonest *Atlantic* variety—is *Exocoetus volitans*. Following the flag (I suppose), it is also to be seen volplaning in Hawaiian waters. In this species the pectoral fins are as long as its body. To round out the collection of American fliers, we have the largest of all the species, *Exocoetus californicus* (*vel Cypselurus californicus*)—the great flying fish, 18 inches long—inhabiting the coastal tides of California. It is also appropriate that the zoologist who knows most about these piscian wonders should be David Starr Jordan, of Stanford University. The flight mechanism and methods studied by him and his former assistants, Professors Gilbert and Evermann, are briefly as follows: "The flying fish of the open sea live in schools, and 'fly' a distance of a few rods to an eighth of a mile, rarely rising more than 3 or 4 feet out of the water. Their movements in the water are very rapid, and from this alone do they gain the force that impels them through the air. The apparent vibration of the pectorals in the air does not to any appreciable extent aid their progress over the water. On rising from the surface the movements of the tail are continued until the whole body is out of the water. The vibration of the pectorals is not a truly flying movement, but is due to the resistance of the air itself. In the water both ventrals are folded; when in air both pectorals and ventrals are spread to act as parachutes or wings to hold the body in air. When the fish begins to fall, and its tail touches the water, the tail again begins to move, enabling it once more to resume flight. In full flight the fish takes advantage of the wind, turning about to fly with the favoring breeze."

Although I have rather carefully watched flying fish on several oceans and tidal rivers I have never been fortunate enough to see them "fly," i. e., use their lateral fins as a means of progression through the air. Once I saw a school of freshwater flying fish 100 miles up a tropical river, but they belonged to a different genus, and perhaps order, than *Exocoetus*. During this journey into the

interior of South America my four companions and I watched and discussed the movements of these small, sunfish-shaped skimmers of the river surface. They did not "fly" in the air so much as they skipped over the calm water of the Potaro in a perfectly straight line for from 5 to 20 yards by a sculling motion of the tail. The fore part of the rounded abdomen also rested on the surface and seemed to furnish some support as the fish scudded along. Doctor Gifford, who watched many of these fish very critically, feels certain that he never saw one, on that journey, rise free of the water and actually "fly" through the air, like *Exocoetus*. On the other hand, he believes he has seen *Cypselurus californicus* use his pectorals, like a huge dragon fly, as an actual propeller. He has not seen them fly more than 100 yards and then not more than 2 or 3 feet above the waves.

I have discussed this matter with many observers, in particular with an old sea captain interested in natural history who had for hours at a time watched flying fish all over the world. He placed the limit of flight in any species he had seen at 200 yards, and the highest point of their trajectory at 4 feet. Ault (Geographic Magazine, Dec. 1922, p. 642) agrees with Gifford in believing that some of these fish are able to continue flight, changing direction and going much farther than momentum alone could carry them. He claims that the vibrations of the wing fins have been seen frequently by several observers.

Another authority, Doctor Hankin, is of opinion (Nature, Aug. 18, 1921) that although at the beginning of their glide they may flap their large triangular pectorals a few times and though they vary the position and planes of part or the whole of their transport fins, as the soaring hawk curls and arranges his wings to take advantage of a favoring wind or air current, yet it is the propulsion out of the water and the succeeding glide that constitute the so-called flight of the flying fish; they do not fly as birds do. The mechanism of this locomotion has, as every naturalist knows, been discussed innumerable times in literature like its analogous process, the soaring of the hawk or vulture.

In Barbados I had an opportunity of seeing the fisher boys catch the variety that abounds on that island coast. They are a dark-backed, trout-like species about 10 inches in length, their pectorals attached to the bodies like the gossamer wings of huge dragon flies. They also gave one the impression of a folded fan with little rudder-like accessories. I saw how these fish are caught in that particular part of the island. They are first attracted by pieces of meat—often distinctly odorous—inclosed in a wicker container which is "jiggled" up and down in the water from the stern of the fisherman's boat. The fish thus enticed are landed by means of a dip or other net.

Capt. John Bollons, master of the Government steamship *Tutanaki* and a naturalist of local repute, told me that during his thirty years of service in the South Pacific he had made a considerable study of flying fishes, and that he had often seen the large flying fish (*Cypselurus melanocercus*) rise as much as 6 feet clear of the water and without again touching it volplane (the captain would not say "fly") a quarter of a mile. On many occasions he had observed them "bank" and vary their direction as often as three times on each occasion and as much as 30°–40° during the night.

An officer of the mercantile marine, whose powers of observation I regard as worthy of consideration, tells me that he has often caught one of the Pacific flying fishes on board his ship, and that they can fly to a deck even to 10 feet from the water level. They usually "fly" on board at night, and he thinks they are attracted by the lights of the vessel. In proof of the latter statement he points to the method of catching them in Polynesia, by means of the flare on a canoe and a dip net. But why does the light attract the fish? Quien sabe?

Having quoted some recent literature on this apparently obscure subject, suppose we listen to what Adriaan van Beckel has to say about it. He sailed to South America from Holland nearly 250 years ago, and in his "American Voyages" tells many interesting stories about the flora and fauna he studied in his travels. Recently, my friend, Dr. Walter Roth, of Christianburg, British Guiana, an author well known to students of Indian folklore, translated this charming Dutch work, and the following quotation is from his original manuscript, which he was good enough to present to the writer. "As regards the flying fish, we saw various shoals raise themselves in flight to the height of about 8 or 10 feet, and cover 50 or 60 paces before they fell again into the water to moisten their wings, and acquire renewed strength against the bonitos (implacable cannibal fish that are always chasing the flying fish and driving them to seek refuge in aerial flights), who sometimes catch them as they fall or spring out of the water and grab them as they fly. Besides bonitos, the flying fish have yet another enemy, being a certain kind of bird, which shoots down on them as they fly out of the water to save themselves from the bonitos. Our constable brought me the first flying fish which, followed by one of the said birds near by, happened to fall into our ship. It was of the shape, color, and size of a herring, the back a little bit thicker, and the extreme front of the head roundish, like a sea bream, with the wings above the belly—very like a bat's."

For the naturalist the chief attraction that Niuafoou in the Tongan group holds is its "Malau," one of the several species of Megapodes that have preserved their reptilian habits to the extent of laying their eggs in the sand of the sea shore and allowing the hot sun to do the hatching. When I was in Nukualofa, the capital of

Tonga, Dr. C. M. Dawson, chief of the medical service and all-around scientist, gave me one of the eggs of this curious bird. This specimen is of a purple-brown color, an egg twice as large as the average hen's egg, the bird that laid it being smaller than the average hen. The Malau resembles closely the Celebes species (*Megacephalon maleo*) described by Alfred Wallace in his "Malay Archipelago." "It is," says he, "in loose, hot, black sand that the maleos deposit their eggs. In the months of August and September, when there is little or no rain, they come down in pairs from the interior to certain favorite spots and scratch holes 3 or 4 feet deep, just above high-water mark, where the female deposits a single large egg, which she covers with about a foot of sand, and then returns to the forest. At the end of 10 or 12 days she comes again to the same spot to lay another egg, and each female is supposed to lay 6 or 8 eggs during the season. The male assists in making the hole, coming down and returning with her. The appearance of the bird when walking on the beach is very handsome. The glossy black and rosy white of the plumage, the helmeted head, and elevated tail, like that of the common fowl, gives a striking character. * * * The eggs are so large that it is not possible for the body of the bird to contain more than one fully developed egg at a time. After the eggs are deposited in the sand they are no further cared for by the mother. The young birds on breaking the shell work their way up through the sand and run off at once to the forest." Knowlton adds to the foregoing (Birds of the World, p. 270): "That the nesting habits of these Megapodes are admirably adapted to the structure and present life of the birds is beyond question; but how these habits could have originated in the first place is difficult to understand. Under present conditions, if the birds were required to incubate their eggs, serious difficulties would arise. With an interval of 10 or 12 days between the laying of each egg, a period of some two or three months would elapse between the first and the last egg. If the eggs were left until the last was laid, the first ones would be subject to climatic injuries as well as destruction by predatory animals; while if the female began incubation with the laying of the first egg, it would require her to remain sitting for three months, which would be impossible. It has been suggested that these nesting habits may be the survival of a habit enjoyed by a remote reptilian ancestor, but this is too improbable. Others think that it arose from the birds covering up and concealing their eggs, which seems not unreasonable; yet if this is true, it is difficult to see how they could have become developed to the point where the young can fly from the time of exit from the shell."

The parrots of Fiji are renowned among ornithologists and they have often been described in the literature of natural history, even if they are not quite as popular among colonial planters because of their love of such forbidden fruits as bananas, coconuts, and pawpaws. Surely, however, something can be forgiven such lovely creatures. Perhaps the most elaborately decorated of them all is the Yellow-breasted Parrot (*Pyrrhulopsis personatus*), 22 inches in length. He is probably much rarer than he was twenty years ago. I was unable to locate a single caged specimen among the hundreds of pet parrots to be found on the various islands, although I inserted a request in the Fiji Times and Herald asking owners of the yellowbreast to allow me to see their pets. In several instances I discovered that this fine bird had been caught and tamed but had died after a caged or confined life varying from five to fifteen years. Their places were not filled because no young parrots were on the market. It is quite different with the crimson-breasted species from Kandavu. Here the beautiful *Pyrrhulopsis splendens*, although unprotected by law (on account of his fruit-eating propensities), easily holds his own in spite of the large numbers captured and sold by the natives to tourists and others.

Although not as elaborately decorated as the yellowbreast, *P. splendens* is a very attractive species, whose length is 18 to 20 inches, with the head and all the upper surface crimson; across the nape a wide, deep-blue band; back, rump, upper-tail coverts, and wings bright green; primaries and their coverts, as well as the outer secondary feathers, blue; lastly, as a striking contrast, the eyes are deep orange. It is a question whether this species was not at one time confined to Kandavu and whether the individuals found on Viti Levu, for example, were not introduced from the former island. Be that as it may, wild examples are rare outside Kandavu. This one of the four *Pyrrhulopses* is the favorite cage bird in the colony, not only because of the abundant supply of young birds but because of its talking powers, display of affection, and intelligence, and because it practically never screams nor makes other disagreeable noises when in captivity. Although their rather shrill monotone is a common sound in the Kandavan forest, these birds seem to abandon loud notes when in captivity. They are fair talkers and whistlers, but in exhibiting these accomplishments do not make themselves a nuisance to the neighborhood, as do some of the other large parrots.

Some years ago the Samoans were in the habit of making excursions to Fiji to shoot "kakas" and other birds of bright plumage, that they might weave the feathers into their mats. It is also said that they were not averse to trapping or buying live birds

that they might pluck regular crops of feathers from the unfortunate parrots. This cruel practice continued until the arrival in the colony, as governor, of that sympathetic and well-known naturalist, Sir Everard im Thurn, who put an end to the scandal. The large Fijian parrots built their nests in hollow trees, and generally 20 or 30 feet from the ground. I discovered one nest in a decayed stump less than 5 feet high. The central hole was 8 inches across and the nest was a very primitive affair, consisting only of the débris that had accumulated in the bottom of the excavation. There were three, nearly round, dirty-brown eggs which, when cleansed, became uniformly white. They measured $1\frac{3}{16}$ by $1\frac{3}{8}$ inches.

The other species of this interesting genus are peculiar to (or the types hail from) Taviuni, Vanua Levu, and Koro, respectively. They differ from the Kandavan variety mainly in the amount of blue on the nape of the neck, it being entirely absent in the first mentioned and seen only as an inconspicuous streak in the other two.

In about 1 per cent of the long-tailed Fijian parrots cases of heterochrosis occur; that is, the red, green, and blue feathers in the birds' plumage to a greater or less extent change to yellow and white. Although this color alteration is abnormal it frequently is seen in perfectly healthy subjects of great intelligence and vivacity. Moreover, the alternations often result in color combinations far surpassing in attractiveness the plumage tints of the normal parrot.

The chief glory of Fiji's avifauna undoubtedly lies in her wild fruit pigeons and doves, several of which are found only on the islands of the group. The nutmeg pigeon, so called from its favorite diet, is *Globicera pacifica*, with an iridescent, wine-colored plumage and a remarkable stomach lined with horny spines to grind off and pulpify the arillus or "mace" from the wild nutmegs on which he chiefly subsists. The equally beautiful Chili piegon, or ruve, *Janthoenas vitiensis*, flourishes on red-hot capsicums.

Of the wonderfully feathered little fruit doves much has been written; indeed it is quite impossible to describe their gorgeous coloring; they must be seen to be appreciated. Male and female are quite differently feathered in all the species, the male golden dove (*Chrysaena luteovirens*) having an olive-yellow cap fringed with yellowish, the remainder of the body being mostly clothed in a covering of lovely, separated, glossy, lanceolated, golden feathers. He has a yellow-green tail; while the female is greenish throughout; indeed, goes under the popular name of the green dove.

Then, there is the crimson-capped dove (*Ptilinopus perousei*) that looks white as it flies, but is really a remarkable study in dark purple, bronze-green and white, the first and last colors predominating. This beautiful dove sports a crimson cape over his shoulders

and the white feathers of his breast are split at their ends, the resulting points being tipped with red. The female is less elaborately adorned but is yet extremely attractive.

Still more wonderful in its truly flamboyant attire is the far-famed, though rare, flame-colored or orange dove (*Chrysaena victor*), whose flight through the forest has been aptly likened to "the passage of a rocket on a dark night." The male bird has a velvety, olive-colored cap with a bright yellow border, the rest of the body-covering, both above and below, being composed of closely applied, hair-like feathers of a brilliant, glossy orange-red; "flame-colored" describes it more accurately. The entire plumage of the female is rich green; yellowish-green on the head and throat. I have never seen a more impressive study in feathered monochrome than is presented by this beautiful little dove. Finally, one of the most attractive of these *Columbiformes* is the Fijian ground dove (*Gallicolumba stairi vitiensis*), intermediate in size and, perhaps, beauty between the smaller doves and the larger pigeons. The general coloration of this species is dark brown with bronze and purple reflections. He has a genuine "coo" as his call note, and is still to be found in those localties that are free of the mongoose. In Viti Levu some individuals still survive. They have learned to avoid ground feeding as much as possible, and to build on the small branches of high trees to which the enemy can not climb. A noticeable character of some of these Fijian birds is their "barking" notes—those of the golden dove in particular. In the deep jungle one is often startled by a succession of clear or hoarse dog-like sounds, so familiar that if one does not know their origin they are readily attributed to a dog that has strayed from home.

HISTORICAL TRADITION AND ORIENTAL RESEARCH[1]

By James Henry Breasted
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It has often been remarked that the outstanding trait of the untrained mind is credulity. The rationalization of man's views of the world has been a very slow process and it is still very far from a completed process. It has commonly been thought to have begun with the Greeks, but its origin must be sought in the Orient in a period long before Greek civilization had arisen. The Edwin Smith Medical Papyrus, acquired in 1906 by the New York Historical Society, discloses the inductive process of scientific investigation already in operation in the seventeenth century before Christ. For example, this document contains the earliest occurrence of the word "brain" anywhere appearing in surviving records of the past. The word is unknown in Old Testament Hebrew, in Babylonian, Assyrian, or any of the ancient languages of Western Asia. The organ itself, therefore, was evidently discovered and the recognition of its various functions was begun for the first time by these physicians of early Egypt in the thousand years preceding the seventeenth century B. C. The observations recorded in the Edwin Smith Medical Papyrus show that its author had already observed that control of the members and limbs of the body was localized in different sides of the brain; and the recognition of localization of functions in the brain, mostly the work of modern surgeons within a generation or two, had already begun in the seventeenth century B. C., at a time when all Europe still lay in savagery or barbarism.

I hold in my hand part of an original transit instrument, made as stated by the inscription upon it, by no less a king than Tutenkhamon, in the fourteenth century B. C. It did not come from the tomb of Tutenkhamon, but was apparently made by him for the tomb of his (or his wife's) great-grandfather, Thutmose IV (fifteenth century B. C.). This and another such piece now at Berlin, are the oldest scientific instruments of any kind now known to be

[1] Reprinted by permission from the Proceedings of the National Academy of Sciences, vol. 10, No. 7, July 15, 1924.

surviving. It was used for determining meridian time, especially at night, in order that the observer might then set his water clock, with its 24-hour divisions—a division of the day which thence passed over into Europe in Hellenistic times, whence it was transmitted to us.

Now Herodotus reports a tradition current in his day (fifth century B. C.), that the Greeks were greatly indebted to Egyptian knowledge. This tradition has in recent times been universally rejected; but the documents submitted here to-day may serve at least to illustrate the fact that there was much truth in the tradition transmitted to us by Herodotus, and that its complete rejection by classical prejudice is unjustifiable.

The fact that the early Egyptian scientist employed an inductive method as far back as the seventeenth century B. C. does not, however, mean that he had completely banished from his mind all belief in magic or in supernatural forces. This truth has been well demonstrated for later ages by Prof. Lynn Thorndyke in his monumental two volumes on the History of Magic and Experimental Science—a work of which America may well be proud. Undoubtedly the Greek took the longest step in freeing his mind from inherited religious and traditional prepossessions. Using astronomical observations undoubtedly drawn from Babylonia, Thales predicted a solar eclipse in 585 B. C. Astonishing as it seemed to the Greeks, there is little probability that this feat was an unprecedented achievement. What *was* unprecedented, however, was the revolutionary generalization which Thales based upon his ability to make such a prediction. For he banished the erratic whims of the gods from the skies and discerned the sway of natural law throughout the celestial world. To tear away and fearlessly to trample underfoot beliefs and superstitions which had been sanctified by age-long religious veneration demanded dauntless loyalty to his own intelligence. This first supreme enthronement of the human mind was probably the greatest achievement in the career of man.

We can pay no greater tribute to such Greek thinkers than to recognize that, although they put credulity to rout, they could not banish it altogether. It has survived with extraordinary persistence down to the present day, even appearing in the person of a distinguished statesman who once occupied high office in this city. * * *

In modern times it was of course the tremendous significance of the discoveries of Galileo which most impressively reproclaimed the supremacy of natural law and the sovereignty of the human mind in discerning that law. In this new home of science * which we are now dedicating, there is nothing which more nobly illustrates its

* The National Academy of Sciences Building.

high mission than the dramatic power with which Lawrie's immortal bronze discloses the simple and dauntless figure of Galileo confronting theological dogma with the majestic facts of the universe.

From Galileo's struggle with the church to Huxley's debate with Gladstone, the heavy guns of natural science have dealt tradition one destructive blow after another. It has been under this destructive attack at the hands of natural science that historical criticism has grown up in modern times since Niebuhr. Indeed it has been no accident that in our own country the first serious discussion of the Old Testament narratives in Genesis and Exodus was written by Thomas Cooper, who was the associate of Priestley in the discovery of oxygen. Cooper was Thomas Jefferson's appointee as first president of the new University of Virginia; but in the Virginia of that period the social feeling against Cooper for having assailed the literalistic interpretation of the Old Testament was so strong that Jefferson was unable to secure his induction into office. Jefferson's influence, however, secured Cooper's appointment as president of the University of South Carolina, where public opinion was at first not so strong against him as in Virginia. It is interesting to note that before the end of the twenties, that is less than a century ago, conservative sentiment was strong enough to bring about Cooper's dismissal from the university, although his personal popularity was such that he was promptly appointed to codify the laws of the State, and the first legal code of the State of South Carolina was edited by this gifted representative of natural science and historical criticism.

The merciless critical scalpel which had not spared Hebrew tradition was equally unsparing in its treatment of the cherished classical heritage from Greece and Rome. The tales of Romulus and Remus, the Trojan War and the entire cycle of legends which were linked with it, were shorn away. A critical attitude of universal negation arose. It included the whole Mediterranean and oriental world: Rome, Greece, Hebrews, Babylonians, Assyrians, and Egyptians. Historical criticism would not allow that early man at the beginning of the age of writing had ever heard and transmitted an echo from earlier ages, which, because they possessed no writing, could only send on their story in the form of oral traditions. This attitude of the historical critic may be compared with that of an observer who stands on a mountain peak, and looking off across a distant landscape to a dim horizon shrouded in mists and cloud, insists that the intermittent glimpses of mountain profiles which vaguely emerge on the far-away skyline can not correspond to any reality. In short, without ever having been himself on the ground to investigate, he denies the existence of the phantom mountains on the horizon.

The orientalist, if he be something more than a philologist, may be compared with the explorer who pushes out to that distant horizon, and is able to determine on the ground whether the phantom mountains really exist. Such investigation is, however, relatively recent and the historical critic could hardly anticipate that it was coming. He seemed to be quite safe in sweeping away all early human tradition. It dealt with a world of gods, demi-gods and heroes; it was dominated by the whims and caprices of angry or jealous divinities, and it was filled with impossible wonders and prodigies. How could a soundly critical historian accept narratives which seemed so manifestly impossible? We must grant that under the circumstances rejection complete and unqualified seemed the only safe course.

Such critical negation was supreme when 50 years ago archeology began to reveal with startling vividness the facts and the daily equipment of human life in the very ages with which the rejected traditions dealt. In the seventies of last century the excavations of an untrained observer from the outside disclosed an astonishing vision of pre-Greek civilization at Tiryns, Mycenae, and Troy. The incredulity with which these discoveries of Heinrich Schliemann were greeted by the classicists was highly characteristic. His excavations recovered and exhibited to the incredulous eyes of the destructive critics the whole material equipment of daily life from the very age of the Trojan war (or wars), and from the very city in and around which that war was waged.

Similar revelations, involving far earlier periods of time, rapidly disclosed the successive stages of the human career from a remote antiquity, reaching well back of the beginnings of the world as dated by an alleged "Biblical" chronology. In dealing with the traditions of these earlier ages, the orientalists soon developed a similar school of negative criticism. Such traditional accounts were promptly thrown into the discard. Maspero's bulky history of the oriental peoples, still a standard work on most modern library shelves, tells us that Menes, the first king of the First Dynasty of Egypt, was a purely mythical or legendary figure. Nevertheless we now possess his tomb, and in our collections at the University of Chicago we have a piece of his personal ornaments, a gold bar bearing his name in hieroglyphic—the oldest piece of inscribed jewelry in existence. Since 1894 thousands of prehistoric graves have been excavated along the margin of the Nile Valley, revealing to us the successive stages of human advance for many centuries before the once legendary Menes.

Much the same process is going on in the investigation of Babylonian history. Even the mythical hero Gilgamesh, the original of

the European Hercules, bids fair to emerge at last as a remote city king of early Babylonia, who gained a reputation for his prowess in war till he became the typical and proverbial strong man of all ages.

The crowning disclosure in this unprecedented series of unexpected revelations has just come from Asia Minor. Nearly 20 years ago the German Assyriologist, Hugo Winckler, visited the mounds of Boghaz (or Boghaz Köi—"Boghaz village") in central Asia Minor. As he walked over the ruins he kicked up with his boot heel several cuneiform tablets, lying practically on the surface. Below were piled the clay tablet archives of the Hittite Foreign Office, the earliest of which had been lying here at the capital of the Hittite Empire since the middle of the second thousand years before Christ. The result has been the decipherment of ancient Hittite or rather a whole group of Hittite dialects. The Great War has intervened and since Winckler's death the progress of examining this enormous body of archives has unavoidably been very slow. We owe a great debt especially to Hrozny and Forrer for the invaluable disclosures which they have wrung from these documents.

One of these tablets reports a *war of Atreus, King of Achaia against the king of Caria* at about the middle of the thirteenth century, that is about 1250 B. C. There can be no doubt that in this tablet we have a contemporary reference to the cycle of Trojan wars—a reference which must be regarded as an irreproachable historical source, as old as the events which it records. Thus out of the lost oriental background of Greek history in Asia Minor comes a *written* document confirming a Greek tradition, born in an age when the Greeks themselves still lacked writing. Because writing reaches further back in the orient by nearly three thousand years than it does in Greece, we are therefore able to confirm Greek tradition out of contemporary written sources.

It has long been recognized that in the early development of Greek civilization the cities of Asia Minor took the lead. Thales, who lived in one of these cities, was an example of this early stage of Greek culture in Asia Minor. It is also evident that the inland background of oriental culture contributed much to this early development of Greek civilization on the western fringes of Asia. It is out of this newly recovered oriental background that we are slowly regaining the earlier forerunners of Greek civilization.

This contemporary reference to the Trojan war is an epoch-making revelation, which must react powerfully upon our treatment of early human traditions. It at once demonstrates that such traditions must not be thrown to the scrap heap, but rather carefully divested of gods and goddesses, prodigies and wonders, and then examined for the nucleus of sober fact upon which the legendary tale has been built up.

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As we look back upon our earliest historical horizon, we now know that the men who stood there in the gray dawn of the age of writing, were able to hear echoes of a remoter past, transmitted in the form of oral tradition of which some portion was then committed to writing and thus survived. In our modern effort to recover and reconstruct the story of man's past career, we have thus rehabilitated a new body of sources, however cautious it behooves us to be in making use of them. Not credulity, but historical method demands that we now recognize these traditions, or the nucleus of fact to be drawn from them, as a body of sources now to be restored to their proper chronological position in the succession of surviving evidences which reveal to us the past career of man on earth.

We are the first generation of men able to survey that career without a serious break. As we marshal the evidence for its successive stages, we humanists stand shoulder to shoulder with the natural scientists; for as we look backward it is the materials and the methods of the geologist which confront us first. The geologist is succeeded by the paleontologist, the anthropologist, the anthropogeographer and the archeologist. It is at this point, on the border land between the investigations of the natural scientist and those of the humanist that we must insert these long discarded echoes from an age able to transmit only oral tradition, the true value of which oriental research has now interpreted to us. The Homeric songs of the Trojan War can no longer be regarded as exclusively noble literature, of purely legendary content, and in the presence of these earliest surviving monuments of science the Greek tradition of substantial Egyptian contributions to knowledge must not be rejected as baseless. There is every possibility that the tombs of Egypt may yield us further scientific treatises like this great Edwin Smith Medical Papyrus, and we still cherish the hope that the thirty-five or forty chests, boxes, and caskets still lying in the innermost chamber of the tomb of Tutenkhamon with their seals unbroken, may contain written documents.

SHAMANISM OF THE NATIVES OF SIBERIA

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[With 2 plates]

Shamanism is the name loosely given to certain religiomagic beliefs and practices found generally in primitive communities in which the officiating priest or functionary is a shaman. It does not designate a specific religion, but a certain religious attitude based on the animistic view of nature, the view that the world is pervaded by spiritual forces—gods and spirits—which affect for good or ill human life, and that certain persons can enter into close relations with these powers and control them, and thus be mediators between man and the spirit world. In fact, that men, or at least some men, can enter into communication with the spiritual powers and use them for benevolent or maleficent ends is a universal belief, the common presupposition of magic as well as of religion. But more specifically the term Shamanism is at present applied to those semi-religious and semimagical procedures of the ecstatic wizards among the native tribes of Siberia. The Shamanism of these peoples—commonly called the Ural-Altaic tribes—may be considered as a specialized and highly elaborated form of the universal practice. It is there associated with a full and varied religion, polytheism or polydaemonism, generally with a supreme god over all, of which it is an essential and central part and connected with sacrifices, liturgical prayers, chants, and formulae.

AREA OF THE SHAMANISTIC CULT

All the peoples of northern Asia, especially of the eastern part of it, the Ugro-Finns, the Tunguse, the Mongolian, and Turkish tribes, were formerly adherents of Shamanism. But Buddhism, Mohammedanism, and, since the Russian conquest in the seventeenth century, Christianity (in its orthodox version), have largely encroached upon it, so that it is now in a moribund condition and rapidly disappearing. It is at present best represented by the

Tunguse who, with the exception of the Manchus, are all Shamanists. It is also to some extent in vogue among the Buryats living west of Lake Baikal (those living on the east and south of that lake having adopted Buddhism in its Lamaistic form), a few Tartar tribes living among the Sajan and Altai Mountains (the so-called Mountain Kalmuks, the Blackforest Tartars, and Shores), and among some Samoyed tribes. On the other hand, Shamanism, in turn, reacted on the new faiths. The Islam of the Siberian Tartars and the Lamaism of the Buryats is greatly mixed up with Shamanistic practices, while the Russian orthodoxy, forced upon the Yakuts and other native tribes of northern Siberia, forms only a very thin veneer over a full-blooded Shamanism. Indeed, old Rusian settlers in those far-off regions have to a high degree become "Shamanized."[1]

COSMOGONY AND WORLD VIEW OF SHAMANISM[2]

Shamanism has its root in a cosmogony and world view, which is substantially common to all Shamanists. According to these the world consists of three spiritual realms—an upper one, a lower, and a middle one. The upper world is composed of seventeen strata or heavens, and constitutes the realm of light, the dwelling of the gods and good spirits who protect and preserve the weak race of man; the lower, composed of seven or nine strata or hells, is the realm of darkness, the abode of fiends, demons, and the damned. Between heaven and the netherworld is the surface of the earth, the habitation of the human race, so that this middle realm is under the influence of both the realms named above.[3] The cause of such a world order was the fall of man as related in the legends of creation: In the beginning all was water, neither earth nor heaven nor sun and moon existed. Then Kaira Kan, the highest god, created first a being which was like himself and called it man (*kishi*). Kaira Kan and the man were quietly floating over the water like two black geese. But man was not contented with this blissful state, he wanted

[1] "Shamanism seems to be such a natural product of the continental climate with its extremes of cold and heat, of the violent burgas and burans (wind- and snow-storms), of the hunger and fear which attend the long winters, that not only the Palaeo-Siberians and the more highly cultivated Neo-Siberians, but even Europeans have sometimes fallen under the influence of certain Shamanistic superstitions. Such is the case with the Russian peasants and officials who settle in Siberia and with the Russian Creoles." M. A. Czaplicka, Aboriginal Siberia. A study in social anthropology. Oxford, 1914, p. 168.

[2] Mainly abridged from Wilhelm Radloff, Aus Sibirien, Leipzig, 1884, Vol. II, pp. 1 ff.

[3] Radloff, op. cit., p. 3, would derive the conception of a world composed of strata from the layers of the mountains, which the dwellers in the mountainous regions have observed. But this, as in fact the whole rather lofty and elaborate cosmogony of the Siberians, may be due in part to the influence of Mohammedanism with its seven heavens and seven hells (comp. Holmes anniversary volume, Washington, 1916, p. 49), and of Buddhism with its still more numerous heavens and hells.

to rise higher than Kaira Kan. In consequence of this presumption he lost his ethereal nature and sank into the bottomless water. Kaira Kan out of compassion made man raise himself out of the depth, at the same time bidding him to bring up the earth out of the water as habitation for man since he could no more fly. But man, still rebellious, in bringing up the earth put part of it into his mouth in order to secretly create a land for himself. But when he came up the earth swelled in his mouth so that he could not breathe and would have choked if he had not spit it out at the command of Kaira Kan. The land which Kaira Kan created was even and smooth, but the earth which came out from the mouth of man sprawled in all directions and covered whole land areas with swamp hills. Kaira Kan named the man Erlik and banished him into darkness where he became lord (*Kan*) of hell. Then Kaira Kan caused to grow from the earth a tree with nine branches and under each branch created a man. These nine men became the ancestors of the nine tribes of mankind who people the earth.

Erlik by corrupting men got them into his power. Kaira Kan in his anger over the wickedness and folly of mankind withdrew to the uppermost of the seventeen heavens and banished Erlik to the third stratum of the subterranean realm of darkness. Erlik, persisting in his impiety, built with the evil spirits a heaven for themselves in imitation of Kaira Kan's heaven. But Kaira Kan shattered it. The fragments of Erlik's heaven falling upon earth, which till then was even and smooth, caused the high mountains and deep valleys. This time Erlik was thrust down to live forever in the lowest world of darkness.

From Kaira Kan came as emanations the other high gods: Bai Ulgan, highest after Kaira, who lives in the sixteenth heaven, Ky Sagan, in the ninth heaven, and Mergen, in the seventh heaven, where is also mother sun, while father moon lives in the fifth heaven, where is also the demijurge creator. Bai Ulgan's two sons are in the third heaven. In this third heaven are also located the "sea of milk," or the spring of all life, the mountains of the gods, and the paradise to which go the souls of the just and the blessed. The latter are mediators between the gods of heaven and their offspring on earth, helping them when they are in distress.

Beneath this realm is that of *Jersu*, earth, conceived as a community of spirits, as an animate whole, at whose navel lives Jo Kan, whose power is almost equal to that of Kaira Kan. Besides him there are high lords (*Kans*), seventeen in number, corresponding to the seventeen mountains and the seventeen seas. Where the seventeen seas unite lives the Ocean Kan. There is also an Altai Kan, the national or folk god. All these gods and demigods are, like the heavenly lords, helpers of man and creative powers, but only

the Jersu (earth) lords can be approached directly by ordinary men, who offer them gifts or revere them by casting a stone on a pile, or sing them hymns of praise.

Contrary to these are the dwellers in the nine strata of the netherworld, the evil spirits with their King Erlik Kan, enemies of man who endeavor to harm him. From Erlik issue all misfortunes, from poverty to death. He also seduces men to sin. From birth to death there is a struggle between the good spirits and the evil ones about man. At the birth of a human being a good spirit is sent down by Bai Ulgan to supply it with life from the "sea of milk," and ever after to remain at his right shoulder, guiding him aright. But simultaneously Erlik sends up a devil from below to stand at the left shoulder and mislead him. At death the soul goes to Erlik to be judged by him, and both spirits give a record of his deeds. If the good deeds predominate, the soul is delivered by the good spirit from the realm of darkness and carried to the third heaven; if evil is greater than good, it is dragged to hell and cast into a gigantic caldron filled with boiling tar. Erlik is nevertheless called "Father" Erlik, "because all men belong to him, and at the end he takes the lives of all." [4]

Now, only the earth lords can be approached directly by ordinary men without an intermediary priest. Far different is it with the great lords of the upper and the under world. They must be approached through the mediation of the spirits of the dead—in case of the good gods through the *Somo*, the nine guardian ancestors of men. But the power to control the ancestral and other spirits is inherent only in certain families. This power manifests itself when a member of such a family is seized with an ecstasy and becomes inspired and in this state is able to act in the capacity of an intermediary between man and the spirits.

To sum up the above delineation of the world view of Shamanism, it may be said its philosophy is the personification of the forces of nature, the view of the world as pervaded by spiritual agencies. Man stands under the influence of two opposite powers, the power of light and the power of darkness. The first, obviously, dwells in

[4] Erlik is in many of his aspects a counterpart in Shamanistic mythology of Ahriman (Angromainyus) in Zoroastrian theology. The conception of two spirits, one good and one evil, accompanying man through life and recording his deeds after death, has some analogy in Jewish and Mohammedan lore. "Two angels—one good and one evil—accompany man as he returns from the synagogue to his home on Sabbath," Talmud, Shabbath, 119.[b] "The two angels who accompany man testify as to his behavior," Talmud, Hagigah 16[a]. Mohammedan sources also assign two angels to accompany each person through life, the one at his right recording his good deeds, the one at his left his evil doings. Compare Koran, Sura xiii, 12: "Each man has a succession of angels before and behind him, they watch him by the command of God"; and Sura L, 16: "When the two angels deputed to take account of a man's behavior take an account thereof, one sitting on the right hand and the other on the left: he uttereth not a word"; that is, in the hour of death the two angels write down the actions of man, the one on the right the good ones, the one on the left the bad, and man can not produce an excuse for the latter.

heaven, whence comes every good gift; the second power dwells in the source of darkness, in the bosom of the cold, dead earth. Between these two mighty powers lies the surface of the earth, which is kin to man and is teeming with life apprehensible by him, the *Jersu* with its mountains and seas, which supply him with all the necessaries for the maintenance of his physical existence. But the nature of the earth is variable and changeable, offering him no protection against mishaps, losses, and pains. Therefore, man offers his highest reverence to the unknown powers of light and darkness, who control his own destiny as also the earth and its phenomena. But these beings are so mighty and their workings so incomprehensible to him that he dares not enter into direct intercourse with them. For these he needs those specially gifted persons who have an understanding of the divine powers and the authority to control them for the securing of good and averting of evil.

Although the spirits of light are believed to be more powerful than those of darkness, the former need little attention because they are good and kind, while the evil spirits, if not appeased, would constantly do injury. It is also in human nature to accept the good without much reflection, while the evil which man experiences and the misfortunes which befall him stand out clearly in his consciousness. In consequence, the Shamanistic cult consists for the most part in placating and controlling of evil spirits. But Shamanism is not on that account to be termed a devil worship, but a cult of spirits, or a ghost worship. The shaman is not possessed by a devil, but by an ancestral spirit. When thus possessed he ascends to heaven or descends to hell and influences the powers by the spirit in him.

THE SHAMAN—NAME

The word "Shaman" is considered by some to be a corruption of the Sanskrit *Shramana*, Pali, *samana*, an ascetic, which, indicating a disciple of Buddha, became among the Mongolians synonymous with the magician. But the most acceptable explanation of the word is that derived from the Manchu *saman*, pronounced *shaman*, the fundamental meaning of which is "one who is excited, moved, raised," thus answering to the principal characteristics of the shaman. The name shaman is only found among the Tunguse, Buryats, and Yakuts, but it is only among the Tunguse that it is the native name, the Buryats and the Mongols calling their shaman *bo* or *boe*, and the female shaman *odegon* or *utygan*. Among the Yakuts the shaman is called *oyum*, a female shaman, *udagan*, among the Ostyaks, *senin*, female, *senim*. The Samoyeds call their shaman *tadebei*, and the Altaians use the term *kam*, and call the shaman's dealings with the spirits *kamlanie*, i. e., *kam-ing*.

THE SHAMAN—CALL TO OFFICE

In some tribes the office of a shaman is hereditary; in others a predisposition to it suffices. Among the Tunguse of Trans-Baikalia a would-be shaman declares that a departed shaman has appeared to him in a dream commanding him to take his office. Among the Buryats and Lapps the office is usually hereditary, although anyone may become a shaman or be chosen by the gods. The inhabitants of the Altai district in northern central Asia consider that the vocation of a shaman is spontaneously transmitted by inheritance from parents to children, like a kind of incubation. Among the Ostyaks the shaman chooses one of his sons, according to his fitness, to be his successor. The Yakuts believe that Shamanism seizes involuntarily upon the chosen individual. "It is in general no rare occurrence that men who have been struck by lightning are looked upon as chosen by the gods and are therefore admitted to priestly honors. * * * Among the Buryats, if anybody is killed by lightning, it is held to betoken the will of the gods, who have thereby conferred a certain distinction upon the family of the dead man; he is considered a shaman, and his nearest relative enjoys the right of shamanhood."[5] The Tunguse consider children who bleed at the nose or mouth to be destined by the gods to the profession of a shaman.

But in any case, whether succeeding to the office of shaman by heredity or chosen by the spirits or self-chosen, the candidate usually exhibits psychopathic traits. He is shy, distrait and moody, given to hallucinations and trances, or he is subject to epileptic fits. He is fond of solitude and takes to the woods, jumps into fire or water, hurts himself with weapons, and in general betrays the symptoms of an abnormal person. Such abnormality is, however, by no means universal.

When once called to the office of a shaman the candidate is not free to accept or to decline the call. "The power of the ancestors having passed into him, he must needs shamanize. If he resists the will of his ancestors he exposes himself to terrible tortures, ending either in the entire loss of his mental power, becoming an imbecile, or in stark madness, which ends in suicide or death in a paroxism."[6] In general, "the vocation of the shaman is attended with considerable danger. The slightest lack of harmony between the acts of the shamans and the mysterious call of their 'spirits'

[5] Gunnar Landtman, The Origin of Priesthood, Ekernaes, Finland, 1905, p. 98. Compare John R. Swanton in Handbook of the American Indians, II, p. 522.

[6] Radloff, op. cit., p. 16 f. With regard to the shamans or medicine men of the American Indians, comp. A. J. Dixon, "Some aspects of the American shaman," American Journal of Folklore, vol. XXI, No. LXXX, p. 2. Similarly compelling is the call to the office of a *Mutang* among the Koreans, comp. I. M. Casanowicz, Paraphernalia of a Korean sorceress in the U. S. National Museum, Proc. vol. 51, 1916, p. 593.

brings their life to an end. * * * This is particularly so when the shaman is slow to carry out those orders which are intended to single him out from other people. * * * There exist traditions about shamans who were carried away still living from the earth to the sky, about others killed by the spirits or struck down at their first meeting with the powers whom they dared to call upon."[7]

THE SHAMAN—INITIATION

As a rule candidates for the profession of a shaman have to undergo preparatory instruction which is imparted by some expert practitioner. During the time of preparation the novice has to pass through both a mental and a physical training. He is usually segregated and goes either to the forests and hills or else he remains in the inner room the whole time. His imagination is worked upon by solitude, the contemplation of the gloomy aspect of surrounding nature, long vigils and fasts with the use of narcotics, until he becomes persuaded that he, too, has seen the apparitions which he has heard of from his boyhood. The shaman spirits usually appear in the form of animals or birds. The most common guardian spirits of the shaman are the wolf, the bear, the raven, the sea gull, and the eagle. The Yakuts believe that every one of their *Oyums* has his *emekhet*, or guardian spirits, and his bestial image, *ie-kyle*, sent down from above. The *emekhet*, generally a dead shaman, occasionally a secondary deity, always stays near the man it protects.

The novice has also to learn singing, dancing, ventriloquism, and how to beat the drum. But it is not always that a preparatory instruction is necessary. There are shamans who have obtained the requisite powers and qualifications direct from the gods without being previously instructed in the profession.

THE SHAMAN—CONSECRATION

The consecration of the candidate to his office is among some tribes accompanied by certain ceremonies. The candidate on this occasion takes certain vows upon himself and becomes the property of the spirits. Among the Yakuts, an old shaman takes him to a hill or an open field, clothes him in shaman's dress, invests him with tambourine and drumstick, and placing him between nine chaste youths on his right and nine chaste maidens on his left, makes him promise that he will be faithful to the spirit who will fulfill his prayers. Then he tells him where the various spirits dwell, what diseases each causes, and how they may be appeased. Finally the

[7] Czaplicka, op. cit., p. 175 f.

new shaman kills the animal destined for sacrifice, his dress is sprinkled with the blood, and the flesh is eaten by the spectators.[8]

Among the Buryats the consecration of a shaman is very elaborate and expensive, including purifications and ablutions, the sacrificing of many animals, and a numerous personnel of assistants and participants. He is addressed on this occasion: "When thou art called to a poor man, ask little in return for thy trouble and take what is given. Take care of the poor, help them and pray to the gods to defend them against the power of the evil spirits. If thou art called by a rich man, go to him riding on a bullock and do not ask much for your trouble. If thou art called at the same time by a poor and by a rich man, go first to the poor." The candidate repeats these precepts after his mentor and promises to observe them.[9]

MALE AND FEMALE SHAMANS

Most commonly the shaman is a man. The natives about the Altai mountains in northern central Asia allow only men to take part in their sacrificial feasts so that consequently the shamans must be men. Female shamans are found among the Tunguse, Ostyaks, Buryats, and Yakuts, and though with the last they are regarded as inferior to the male shaman, yet are preferred for the cure of mental troubles. The Golds, on the Amur River, also have female shamans, and among the Kamchadales, on the peninsula of Kamchatka, every old woman is looked upon as a witch and interpreter of dreams.[10]

WHITE AND BLACK SHAMANS

The Buryats distinguish between white shamans, who serve the good spirits (*tengris*) of the west, and the black shamans, who serve the evil spirits of the east. The former are honored as those who through their influence with the beneficent powers help and protect men; the latter are feared because through the evil spirits they often work harm to men. For one who has such power over spirits as to drive them out from bodies must be able also to send them into people and make them ill or mad. They may also steal the souls of their

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[8] Comp. V. M. Mikhailovski, Oliver Wardrop, "Shamanism in Siberia and European Russia," Journal of the Anthropological Institute of Great Britain and Ireland, vol. XXIV (1895), p. 86.

[9] Czaplicka, op. cit., p. 187.

[10] Landtman, op. cit., p. 194 ff. In America, according to Dixon (l. c., p. 2), the shamans are predominantly male, though women are by no means entirely excluded. "Among the tribes of Patagonia there was a curious custom which prescribed the wearing of female clothing by male shamans." An analogous custom is found, according to Sieroshevski-Sumner, "The Yakuts," in the Journal of the Anthropological Institute of Great Britain and Ireland, vol. 31 (1901), p. 103 f., among the Yakuts of the Kolmyck district, where the shamans "for want of any special dress, put on women's dress. They wear their hair long and comb and braid as women do. According to popular belief, any shaman of more than ordinary power can bear children like a woman. They even gave birth to various animals and birds."

victims. The Buryats also believe that the white and black shamans fight with each other, hurling axes at one another from distances of hundreds of miles. The black shamans are sometimes killed for their evil deeds. Landtman[11] adds: "Facts go to prove, however, that the distinction between good and evil disposed classes of the priesthood is often arbitrarily drawn, with little or no regard to the means, whether religious or magicial, which they make use of in their practices."

SHAMANS INCARNATED IN ANIMALS

It was stated above (p. 421) that the Yakuts believe that every one of their shamans (*oyums*) has his *emekhet*, or guardian spirit, and his bestial image *ie-kyle*, sent down from above. This incarnation of the shaman in form of a beast is carefully concealed. Only once a year, when the snow melts and the earth becomes black, do the *ie-kyles* appear among the dwellings of men. The incarnate souls of shamans in animal form are visible only to the eyes of shamans, but they wander everywhere, unseen by all others. They often fight, and then the shaman whose *ie-kyle* is beaten falls ill or dies. The weakest and most cowardly shamans are those of the canine variety; the most powerful wizards are those whose *ie-kyle* is a stallion, an elk, a black bear, an eagle, or the huge bull boar. The Samoyeds of the Turukhinsk region hold that every shaman has a familiar spirit in the shape of a boar, which he leads about by a magic belt. On the death of the boar, the shaman himself dies, and stories are told of battles between wizards, who send their spirits to fight before they encounter each other in person.[12]

DEAD SHAMANS

The souls of the departed are generally believed by primitives to be more or less hostile and dangerous to the living. This the more so in case of the ghosts of wizards who were already powerful in life. Hence "the Turanian tribes of northern Asia fear their shamans even more when dead than when alive, for they become then a special class of spirits who are the most hurtful of all."[13] Among the Yakuts the shamans are thought to be transferred after death into evil spirits. The dead shamans are buried with great haste by night or at evening in a remote nook in a grove or in a forest opening, and the place is always afterwards carefully avoided. On the

[11] Op. cit., p. 179.

[12] Mikhailovskii, l. c., p. 133 f. Among the American shamans, according to Swanton, op. cit., p. 522, "two shamans among hostile people would fight each other through the air by means of their spirits."

[13] Rafael Karsten, The Origin of Worship. A Study of Primitive Religion. Washington, 1905, p. 110.

other hand, among the Ostyaks when a shaman dies the ordinary custom of offering divine honors to the dead changes in his favor into a complete and decided canonization.[14] Among the Buryats soon after a shaman dies one of his friends falls in a trance—struck by invisible thunderbolt, launched by gods—and when he recovers announces that the dead shaman's spirit has confided to him the spot in which he wishes to rest. The body is cremated and the ashes are placed in a hole cut in one of the largest trees in the appointed part of the forest. The spot then becomes sacred.[15]

The grave of a black shaman is usually shaded with aspens, and the body is fastened to the earth with a stake taken from that tree.[16]

THE SHAMAN—APPEARANCE AND OUTFIT

"In general," says Sieroshevski (l. c., p. 102), "there is in the appearance of a shaman something peculiar, which enabled the author after some practice to distinguish him with great certainty in the midst of a number of persons. He is distinguished by a certain energy and mobility of the muscles of the face, which generally among the Yakuts are immobile. There is also in his movements a noticeable spryness." Add to this that the shaman is sometimes mentally abnormal, an epileptic or afflicted with some milder neurosis, which is aggravated by the practice of his calling and further reinforced when, as is the case among some tribes, the office is hereditary or runs in families, and that primitives everywhere regard the physically, and more so the mentally, abnormal as due to spirit possession.

Besides these peculiar personal physical and psychical traits, the shaman as mediator in dealings with the spirit world bears during his functions outward signs to inspire the people with feelings of mystery and awe, and to betoken his separateness from the rest of the population. So the shaman at his ceremonies dons a special dress—a coat (*kaftan*) made of cloth or bearskins, hung with pieces of iron—rattles, rings, and representations of animals, or twisted handkerchiefs representing snakes. All these have a definite meaning and purpose and often a mystic character. The Yakut shamans adorn their coats with a representation of the sun with holes in it, and half moon, indicating the twilight that reigns in the spirit land. The mythical animals on the dress signify the monsters in the spirit world which the shaman has to combat, while the iron plates are to protect him against the blows of malevolent spirits. The great

[14] Landtman, op. cit., p. 46.

[15] Bassett Digby, "Forefathers of the Red Indian," Nineteenth Century and After, February, 1923, p. 251.

[16] Czaplicka, op. cit., p. 201. For the description of the elaborate funeral of a Buryat shaman, see Mikhailovskii, l. c., p. 134 f.

SHAMAN OF KAMCHATKA

MONGOL SHAMANESS

shamans are also distinquished by the *amagyat* on their breast, a metal plate, usually copper, adorned with the figure of a man. It represents the shaman's spirit protector or ancestor spirit. It is a particular badge of the shaman's vocation which is given by the old shaman to the new.

But the most important accessory of the shaman's outfit is the tambourine (*tungur* or *tur*) with the drumstick, without which his conjurations have no force and his soothsaying is without validity. The mighty sounds of the magic drum penetrate into the world of spirits, causing them to submit to his will. Besides its power to call up and gather into it the spirits, it serves the shaman as a vehicle in his flight to heaven or in descending into the dark realm of Erlik. The form of the tambourine varies with different tribes. With some it is circular; with others it is oval, with its longest diameter of about 24 inches. Inside the drum, on the long side of the hoop, is a handle in form of a stave. This handle is usually in the crude form of a man, broadening at the upper end to represent a head and forming at the lower end a fork resembling legs. This handle is called the "host" (*tungur asi*) of the drum. Along the arms of the "host"are fastened iron rattles and bells, the number of which is greater or less, according to the rank of the shaman, and corresponding with the number of spirits subject to him. On the outside the skin of the drum is decorated with figures of a symbolic kind, intimately connected with shamanistic beliefs and mysteries (see pls. 1 and 2). Among the Buryats the novice is not permitted to acquire the drum until after the third year from his consecration. To the paraphernalia of a Buryat shaman belong also two horse staves, cut from a live birch tree in such a manner that the tree should not die. They represent the horses on which the shaman flies to heaven.

THE SHAMAN—HIS FUNCTIONS

The ideal shaman unites in his person the offices of priest, healer, and prophet. As a priest he officiates at communal as well as private sacrifices and ceremonials. But the shaman's priestly functions are of secondary importance to and emanate from his other functions. There are many sacrifices and ceremonies at which his participation is not essential. His connection with sacrifice is mainly the fact that as one who knows the will of the gods or spirits and what sacrifices will be pleasing to them on any occasion he determines their nature and the method of offering them.

Sickness is according to the belief not only of primitive peoples but was also of some highly advanced in civilization, as the Babylonians and Assyrians, due to a malevolent spirit that has got into a

man and must be expelled. But only the shaman, who is himself possessed by spirits, is fitted to deal with the demon in such a manner as to bring about the recovery of the patient. The procedure frequently takes the form of a duel between the shaman, or rather the spirit he has conjured into himself, and the spirit that has invaded the patient, in which the latter is vanquished and expelled. This is perhaps the most primitive form of exorcism. The expulsion of disease demons is often accompanied by the use of herbs, purgations, fumigations, and manipulations, which sometimes have remedial effects, so that the shaman is in a measure a forerunner of the physician. Diseases are also caused by the soul of a man having been frightened out of his body and fled away. The shaman pursues it wherever it has gone, even to the prison of Erlik, and restores it to the owner.

But it is the gift of prophecy, or the art of divination, that makes the shaman powerful and is the basis of his other functions. He has direct intercourse with the spirits and actual access to the spirit world, and so obtains knowledge superior to that of ordinary men. By virtue of this knowledge he can give directions about worship and sacrifice, and overcome or drive out hostile spirits. He can foretell the future, find out what is going on in distant places, discover secrets, detect thieves, and answer all manner of questions for which men resort to a soothsayer or prophet. Divination by the shaman may be practiced by the shoulder blade of a sheep[17] or the flight of arrows. But the characteristic method of Shamanistic divination is the seance, or what is locally known as *kamlanie*. In this the shaman by smoking, the use of other narcotics, singing, shouting, dancing, beating of the tambourine, and so on, produces a state of trance or alternate personality. While in this state the spirits take possession of him and reveal their will to him or give him the desired information.[18]

THE SIBERIAN SHAMAN CONTRASTED WITH THE AMERICAN MEDICINE MAN

The main aspects of the Siberian shaman's procedure, as well as the idea of possession by spirits, are found to be well-nigh of universal occurrence in connection with healing, discovering the will of spirits or gods, or soothsaying. One may occur without the others,

[17] Mikhailovskii, l. c., p. 99, quotes the following Buryat tradition about this bone: "A written law was given by God to the chief tribal ancestor of the Buryats. On his way home to his own people he fell asleep under a haystack. A ewe came to the stack and ate up the law with the hay, but the law became engraved on the ewe's shoulder blade."

[18] "The answers of the shaman, or rather of the spirit he conjures into himself, to questions about all sorts of things which there is no natural means of knowing, is perhaps the oldest form of natural divination and the origin of the idea of revelation." George Foot Moore, The Birth and Growth of Religion, 1923, p. 88.

or, again, all are found as parts of the practice of a sorcerer, or wonder-worker. Again, the methods of the medicine man are also found everywhere and largely enter into the shaman's practices. But while the shaman's methods are connected with the cult of spirits and are not fundamentally magical, but rather mysticism of a primitive kind, seeking intimate communion with the spirit world, those of the medicine man are partly magical, partly empirical with the use of naturalistic methods of healing, and are not necessarily connected with the spirit world. The shaman's procedure is mainly based on the fact that he is en rapport with spirits and can control them, while the medicine man generally acts by methods in which the aid of spirits is not essential.[19]

SHAMANISM CONTRASTED WITH FETISHISM

Fetishism, the belief that material objects can become, by appropriate rites and incantations, habitations of mysterious or magical powers, has some kinship to Shamanism. It also springs from animism, being the expression of the notion that the world is pervaded by mysterious spiritual powers. But while in Fetishism the magical power is believed to reside in the instrument or in particular substances, or that the fetish itself is something supernatural, a quasi-personified power or potency, having volition, in Shamanism the will-effect of the shaman is the efficient factor in compelling ghosts or spirits or gods to do his will. In Fetishism the emphasis is laid on the thing, although rites and incantations may be employed in making the fetish; in Shamanism the prime factor is the personality and will of the shaman, although he may employ like means.

THE SHAMAN IN ACTION[20]

The activity of the shaman as a priest or sacrificer, a conjurer up of spirits, and as a prophet is most impressively illustrated by the ceremonies attending the sacrifice to Bai Ulgan, who dwells in the sixteenth heaven, and is next in rank to Kaira Kan, the highest god. It is something like a mystery play or religious drama in which the shaman as conjurer of the spirits is the actor. The procedure of this sacrifice and the ceremonies, conjurations, and incantations accompanying it are very elaborate and are distributed over three evenings.

On the first evening the shaman selects a spot in a birch thicket and there places a new ornamented *yurta* (tent). In the yurta a young birch tree with the lower branches lopped is set up; on one of the

[19] Comp. also Dixon, l. c., p. 12: "As compared with their representatives in other parts of the world, the shamans in America seem to show, both in their making and in their whole character, less reliance on the dead, the ancestral spirits, than do those of other regions * * * deriving his power from animals and natural phenomena."

[20] Mainly abridged from Radloff, op. cit., p. 51 f., and Mikhailovskii, l. c., pp. 74–78.

upper branches a flag is hung. At the bottom of the tree nine steps (*tapty*) are cut with an ax. Round the yurta a penfold is made. Opposite the door of the yurta is the entrance from the courtyard and near this entrance a birch pole with a noose of horsehair is set up. Then a horse agreeable to the deity is chosen, which is held by a person chosen from those present and who is called "holder of the head"—*bashi-tukan kiski.* The shaman waves a birch twig over the horse's back, thus driving its soul to Ulgan, accompanied by the holder's soul, invoking the spirits to come and assist in the action of the sacrificing. The assembling of the spirits in the tambourine takes place with great solemnity. The shaman summons each spirit separately, who answers: "Here I am Kam," at the same time moving the tambourine as if taking the spirit into it. When he has assembled these spirit assistants, the shaman goes outside the yurta, sits down on a scarecrow in form of a goose stuffed with hay and covered with cloth, and moving both arms rapidly like wings, sings in a loud voice:

Below the white sky,
  Above the white cloud,
Below the blue sky,
  Above the blue cloud—
Mount a bird to the sky!

The goose replies by quacking: "Ungai gak gak, ungai gak, kaigai gak, kaigai gak." The shaman himself, of course, does this imitation of the goose's quacking, as he also answers for the spirits. On this feathered steed the shaman pursues the soul (*pura*) of the horse, imitating the horse's neighing. Finally, with the aid of the spectators, he drives the horse to the birch pole with the noose which represents the guardian of the animal's soul. After much straining and drawing, to represent the breaking away and the recapturing of the *pura*, the shaman incenses the animal with juniper, blesses it, and, with the aid of some of the bystanders kills it in a most barbarous and cruel manner. The dead animal is skinned and cut up in a very elaborate manner so that bones are not broken or damaged in any way. The flesh is cooked in caldrons and then laid out on birch branches. The shaman first takes part of it in a wooden dish and offers it to the ancestral and the protecting spirits of the yurta. Part of this offering the shaman distributes among the members of the family and their relatives. The best part is presented to the shaman; the remainder is distributed among the guests. The bones are preserved as consecrated to the gods.

The most important part of the performance takes place on the second evening, when the shaman's journey to Bai Ulgan in heaven is enacted. The shaman invokes with rhythmical chants the various spirits, the lords of the tambourine, the mother of the fire, the seven-

teen lords of the jersu, and Merkyut, the bird of heaven, and offers them a libation. Then he incenses with juniper nine garments hung on a rope and offers them with a song on behalf of the head of the house to Bai Ulgan. As the spirits are gathered the shaman beats the tambourine more loudly. He circles several times the birch tree in the yurta, then he kneels in front of the door and asks the imaginary porter spirit to grant him a guide. By touching the members of the family with the drum on their chests and with the drumstick their backs—the seat of the soul—he purifies and liberates them from all evil, and by putting the tambourine close to the host's ears and striking it he drives into him the spirit and power of his protecting ancestors. At last begins the ascent to heaven. Jumping, shouting with symbolical movements, accompanied by wild gestures, the shaman passes into ecstasy. Then he suddenly places himself on the first step cut out in the trunk of the birch tree, raising the tambourine and thumping it with all his might. He is rising to the sky. From heaven to heaven he passes, riding on the goose, accompanying the ascent by songs and incantations and beating of the drum in various tempos and scales, modulating and changing his voice in imitation of the supposed answerers. At each stage he tells the audience what he has seen and heard. And finally having reached the ninth or even the twelfth heaven, he addresses a humble prayer to Bai Ulgan and learns whether the sacrifice is accepted and receives information concerning the coming weather, the harvest, sickness or other misfortunes, as well as the sacrifices which will be required in the near future. After this interview with Ulgan the ecstasy or delirium of the shaman reaches its climax, he collapses and lies motionless. After a while he gradually rouses himself, rubs his eyes and greets those present as if after a long absence.

The third night is spent in libations and feasting, during which enormous quantities of koumiss and strong drinks are consumed.

THE PURIFICATION OF A YURTA[21]

The highest art of the shaman is brought into play in the so-called purification of a yurta. This takes place on the fortieth day after the death of a member of the family. Only few shamans are competent to carry out this conjuration in a successful manner; rich people, therefore, call on a widely famous shaman for the performance of this service, who is then richly rewarded. The purification is usually performed with the aid of Yaryik Kan, to whom the sacrifice is made for this assistance. According to the belief of the Altaians (shared by many other peoples) the soul of the dead remains for some time in the yurta and is reluctant to

[21] Radloff, op. cit., pp. 52 ff.

depart to the realm of the dead unless in company of other members of the household, or at least of some cattle. Yaryik, being the Jersu prince of the seas, is best able, by driving waterfloods, to force the return of the abducted souls and to drive the soul of the departed to the netherworld.

The belief of the noxious influence of the soul of the dead has its basis in the close family relationship between the dead and the surviving members, which may be considered as the basis of the shamanistic theory and practice. Another cause of this belief is the frequency of epidemics, which, with the lack of sanitary precautions and medical help among the Altaic peoples, are often frightfully devastating and which the people charge to the hostility of the ghosts.

Doctor Radloff had the opportunity to attend such a purification in July, 1860, on the Kengi Lake. In the yurta after sunset were about twenty persons, relatives and neighbors, assembled. It was to be a purification after the death of the housewife. The guests present were quite unconcerned, chatting and smoking. When dusk descended there was heard from a distance the dull sounds of the shaman's drum. By and by the shaman entered the yurta, his chant and beating of the drum gradually softened, passing into a sort of whining and whispering. He held a dialogue with the soul of the deceased, who piteously implored him to let her stay in the yurta with her children. But the shaman mercilessly presses the soul by the power of the drum, which is filled with mighty spirits, until at last he catches it between the drum and the drumstick and presses it to earth. By changing the modulation of his song and of beating the drum he indicates that he has brought the soul to the netherworld. There a dialogue is started with the preceding relatives to whom he has brought the soul of the lately deceased. They decline to accept her. The shaman regales them with vodka, which puts them into a hilarious humor. They sing and are merry, and thus the shaman succeeds in smuggling in the new soul.

When the shaman calls in the aid of Yaryik the merry scene in the netherworld is suddenly interrupted through the inrushing of the flood. The souls cry for help, whine and lament, and the cattle and souls of relatives, which the deceased took along, are driven back home. The shaman imitates the rushing of the waves and roaring of the pressing water. Sometimes the shaman does not succeed in smuggling in the new soul, or the soul escapes and returns to the yurta. Then the scene begins anew.

Returning from Sheol to the upper world, the shaman fell into a frenzy, singing and dancing wildly until he collapsed.

Radloff describes the mighty impression which this wild scene produced on him and the other guests who were all shaken and dumbstruck.

Radloff adds: "The offering of the sacrifice and purification of the yurta are the proper priestly functions of the shaman. In them he has to develop his entire art, and he is the right shaman who understands how to arouse the fear and confidence of his audience, so that they believe that his predictions are true oracles by which the gods try to console and uplight them. Other actions of the shaman are without importance. Pronouncing blessings and thanksgiving other mortals can do, as also the performing of libations to the *jersu*. Weather making and soothsaying are likewise not exclusive prerogatives of the shaman. At birth, marriage, and funerals the shaman has no share, unless these events are accompanied by unfavorable omens, when he is called to avert them by conjuration and exorcism."

THE SHAMAN—HIS INFLUENCE

The shaman as mediator between men and spirits, uniting in himself the many functions described above, enjoys great respect among the people. But he is more feared than loved. His peculiar dress, his wild and convulsive antics, the sound of the tambourine—all lead to powerfully affect the nerves of an unsophisticated people and to strike terror into their hearts. There is also a general craving in man for the mysterious and for spiritual assistance in the adversities and misfortunes of human life which the shaman is believed to satisfy. There is a certain artistry in the shamanistic practice. "Observation justifies the division of shamans into great, middling, and petty. Some of them dispose of light and darkness in such a masterly manner, also of silence and incantation; the modulation of the voice is so flexible, the gestures so peculiar and expressive, the blows of the drum and the tone of them correspond so well to the moment, and all is intertwined with such an original series of unexpected words, witty observations, artistic and often elegant metaphors, that involuntarily you give yourself up to the charm of watching this wild and free evocation of a wild and free spirit." [22]

The shaman is often a man of unusual intelligence and mental resources; he has a profound knowledge of the simple life of his neighbors and gradually acquires the habit of solving their perplexities by a logic of his own peculiar talent, and in many cases the rite performed is to bring about a result which, like rain or sun-

[22] Sieroshevski, l. c. p. 105.

shine, is about to happen, sooner or later anyway, and by shrewd turning to account of accidents he manages to assert and maintain his ascendency. Obviously, it can not be otherwise that many of the divinations and predictions of the shaman are belied by the results, but with childlike credulous peoples one successful instance causes them to ignore or forget all previous failures and deceptions.

Still the shamans could hardly, for any length of time, keep up the belief in their superiority without convincing the people by "miracles"—that is, by executing feats which exceed the power of the laity to perform or to understand—of their supernatural endowments. And, as a matter of fact, according to the testimony of travelers and explorers, some shamans are past masters in the arts of ventriloquism and sleight-of-hand tricks. Thus Bogoras says: "Shamans could, with credit to themselves, carry on a contest with the best practioners of similar arts in civilized countries. The voices are successful imitations of different sounds; human, superhuman, animal, even of tempests and winds, or of an echo, and come from all sides of the room, from without, from above, and from underground. The whole of nature may sometimes be represented in the small inner room of the Chukchee."[23]

"The shamans of the Ostiaks," says Landtman, "strengthen their reputation not infrequently by delusive demonstrations of their invulnerability, stabbing themselves with knives in different parts of the body. For the same purpose the shamans of certain Tartar tribes throw themselves into the fire and seize live coals with their hands."[24] "On another occasion," relates Jochelson, "the shaman took his knife, which was sharp and looked like a dagger, and thrust it into his breast up to the hilt, while emitting a rattling sound from his throat. I noticed, however, that after cutting his jacket he turned the knife downward. He drew out the knife with the same rattling in his throat and resumed beating the drum * * * and returning the knife to him showed through the hole in his coat the blood on his body. Of course, these spots had been made before." Jochelson adds: "However, this can not be looked upon as mere deception. Things visible and imaginary are confounded to such an extent in primitive consciousness that the shaman himself may have thought that there was, invisible to others, a real gash in his body as has been demanded by the spirits."[25] Czaplicka remarks (p. 233): "The practice of stabbing oneself through the stomach with a knife is universal in Shamanistic performances * * *. It

[23] Quoted in Czaplicka, op. cit., p. 231; comp. also W. Jochelson, The Koryak, p. 49, and J. Stadling, "Shamanism" in The Contemporary Review, January, 1901, p. 96, for graphic descriptions of the mimic talent of shamans and their adeptness in ventriloquism.

[24] Landtman, op. cit., p. 141 f.

[25] W. Jochelson, The Koryak, p. 52, quoted by Czaplicka, p. 229 f.

would be difficult to describe all the tricks performed by shamans: Some of the commonest are the swallowing of burning coals, setting oneself free from a cord by which one is bound, etc." There is also nothing new about the pranks of the spirits in our spiritualistic seances: "Sometimes the spirits are mischievous. In the movable tents of the reindeer people an invisible hand will sometimes turn everything upside down and throw different objects about, such as snow, pieces of ice * * *. The audience is strictly forbidden to make any attempts whatever to touch the 'spirits'."[26]

THE SHAMAN—HIS MENTAL ATTITUDE

The question is: Is the shaman himself convinced of the power of his conjurations or is he a play actor, playing a comedy before the superstitious people? In general and a priori it may be said that the rise of so complex a phenomenon as shamanism can not be explained by mere trickery and deception. Only a profound belief in their calling could create the conviction in the people of the miraculous power of the shamans and endow them with the enormous influence which they enjoy among the Siberian tribes. "You can not fool all the people all the time," has its application also in this case. The fact that the shaman employs external devices and artifices to impress or even to deceive the spectators does not exclude the possibility of his earnest belief that he has intercourse with the spirits, is inspired by them and possesses mysterious power. It is the unanimous opinion of investigators and observers of the practices and psychology of wizards everywhere that truth and fiction are closely combined and inseparably blended into one whole in this phenomenon. Just the intense conviction that the spirits speak and work through him may prompt the wizard to use external accessories and to change in good faith the tones of his voice to assist the work of the spirit and to suit its utterance. "Nothing is more superficial," says Reville, "than the opinion of those who see in the sorcerer of the uncivilized peoples only a charletan and a juggler. Without doubt he is strongly driven to the proneness in which charlatanism is not long in becoming in some manner fatal. But in reality, not only do all others around him believe in his superior powers, but he himself believes in them, because the states of hallucination, of ecstasies and mental overexcitement, which are not simulated, have for him as for others the only explanation in the assumption of his intimate intercourse with the invisible spirit."[27]

Among the Yakuts, Sieroshevski says, "Some shamans are as passionately devoted to their calling as drunkards to drink. One of

[26] W. Bogoras, The Chuckchee, p. 438, quoted by Czaplicka, p. 232.
[27] A. Reville, Histoire des Religions, II, 238.

them had severeal times been condemned (by the Russian authorities) to punishment, his professional drum and dress had been burned, his hair had been cut off, and he had been compelled to make a number of obeisances and to fast. He remarked: 'We do not carry on this calling without paying for it. Our masters (the spirits) keep a zealous watch over us, and woe betide us afterwards if we do not satisfy them; but we can not quit it; we can not cease to practice shaman rites. Yet we do no evil.'"[28]

On the whole, it may be said that shamanism includes a truly religious element inasmuch as it confirms the thought that man depends on spiritual forces, and one may agree with Radloff that it "certainly promotes and sustains certain ethical endeavors." And if it was not once "the common cult of all the Turanian peoples" or even the "very earliest religion of the world," as some are inclined to think, it seems certain to be a phenomenon of great antiquity and of relative primitiveness.

[28] Sieroshevski-Sumner, l. c., p. 102.

EGYPT AS A FIELD FOR ANTHROPOLOGICAL RESEARCH[1]

By Professor P. E. NEWBERRY, M.A., O.B.E.

When I received the honor of an invitation to preside at the Anthropological Section of the British Association my thoughts naturally turned to the subject of the presidential address, which, if I accepted the invitation, it would be my duty to prepare. On looking back over the addresses of past presidents of this section since its institution in 1884 I found that no one had dealt with Egypt as a field for anthropological research. It was because of this that I decided to accept the council's invitation, and I am here to-day to bring before your notice some facts regarding the civilization of the country with which I have long been associated, and in which I have spent many years of my life.

In 1897, when the British Association last met in this great city on the Mersey-side, Sir Arthur Evans occupied the presidential chair of this section, and the subject of his address was "The Eastern Question in Anthropology." Surveying the early history of civilization as far as it was then known, he insisted that the adequate recognition of the Eastern background was essential to the right understanding of the Ægean. He laid stress on the part which Crete had played in the first emancipation of the European genius, and pointed out that in Crete, far earlier than elsewhere, can be traced the vestiges of primeval intercourse with the Nile Valley. Nineteen years later, years that were extraordinarily prolific in archeological discovery in every part of the Near East, Sir Arthur occupied the presidential chair of the British Association at Newcastle. He then addressed us on "New archeological lights on the origins of civilization in Europe." Referring to his epoch-making discoveries in Crete he said, "It is interesting to note that the first quickening impulse came to Crete from the Egyptian and not from the Oriental side; the Eastern factor in it is of comparatively late appearance." By that time Sir Arthur's researches had

[1] Address by the president of the Anthropological Section of the British Association for the Advancement of Science at the annual meeting in Liverpool, 1923. Reprinted by permission from the Proceedings of the Association.

led him to the "definite conclusion that cultural influences were already reaching Crete from beyond the Libyan Sea, before the beginning of the Egyptian Dynasties." He further said "the impression of a very active agency indeed is so strong that the possibility of some actual immigration into the island of the older Egyptian element due to the conquests of the first Pharaohs, can not be excluded."

I propose to-day to deal with some of the questions relating to the origins of the Egyptian civilization, and incidentally shall touch upon this Cretan problem. At the end of my address I shall very briefly refer to the much neglected modern Egyptians, and to the need there is to study them. Much has been written during the last 20 years about the origins of the Egyptian civilization, but there are some facts which I think have either escaped notice or have not been duly considered, and there are others upon which, in my opinion, insufficient stress has been laid. I am not going to deal with the physical characteristics of the people, for that is not my province. I shall confine myself to certain inferences that I believe can be drawn from the monuments of predynastic and dynastic times.

It is generally agreed that the habits, modes of life, and occupations of all communities are immediately dependent upon the features and products of the land in which they dwell. Any inquiry into Egyptian origins ought, therefore, to begin with the question, What were the physical conditions that prevailed in the Lower Nile Valley immediately preceding and during the rise of its civilization? Until this question is answered I do not think that we are in a position to deal with such important problems as, *e. g.*, agriculture, architecture, shipbuilding, tool-making, or weaving. The first thing that we ought to know is what were the kinds of trees, plants, and animals that were to be found in Egypt in the wild state, and what was the economic value of the indigenous flora and fauna. We ought, in fact, to know what the country was like in pre-agricultural days. If there was no timber in the country, then it may, I think, be confidently said that the art of the carpenter did not originate in Egypt; that the architectural styles founded on wood construction could not have arisen there; that the art of shipbuilding (at all events of building ships of wood) did not originate there. Similarly, if there were no incense-bearing trees or shrubs in the country, it is difficult to imagine that the ceremonial use of incense arose there. Again, the art of weaving presupposes the presence of sheep or goats for wool, or of flax for linen thread. All these kinds of problems depend upon the natural products of a country, or they did so depend in the early days of civilization.

We are accustomed to regard Egypt as a paradise, as the most fertile country in the world, where, if we but scratch the soil and

scatter seed, we have only to await and gather the harvest. The Greeks spoke of Egypt as the most fit place for the first generations of men, for there, they said, food was always ready at hand, and it took no labor to secure an abundant supply. But there can be no doubt that the Egypt of to-day is a very different place from the Egypt of pre-agricultural times. There has been a great but gradual change in the physical condition of the whole country. In the mortuary chapels of tombs of the Old and Middle Kingdoms, as well as in many of the Empire, are scenes of papyrus swamps and reed marshes; in these swamps and marshes are figured the animals and birds that then frequented them. Among the animals are the hippopotamus and the wild boar, the crocodile, the ibis, and a great variety of water fowl. These animals, and some of the birds, have now disappeared from the region north of the First Cataract. Only very recently has the crocodile become extinct north of Aswân. It was still occasionally seen in the Delta as late as the middle of the eighteenth century, and it was fairly plentiful in Upper Egypt up to the middle of the nineteenth century, but it is now rarely, if ever, seen north of Wadi Halfa. It is the same with the hippopotamus. In the twelfth century this mammal still frequented the Damietta branch of the Nile, and two specimens were actually killed near Damietta by an Italian surgeon in the year 1600.[2] In the Dongola Province of Nubia it was very common at the beginning of last century, and Burckhardt states that is was then a terrible plague there on account of its voracity. In 1812 several hippopotami passed the Second Cataract and made their appearance at Wadi Halfa and Derr, while one was actually seen at Darâwi, a day's march north of Aswân.[3] The wild boar is apparently now extinct in Egypt, but specimens were shot in the Delta and in the region of the Wadi Natrûn during last century. The ibis has gradually disappeared from the Lower Nile Valley, where it was once so common. The last specimen of this bird recorded in Egypt was shot in 1877 in Lake Menzaleh. It is sometimes seen in Lower Nubia, but has now entirely disappeared from Egypt proper.

Much is known about the ancient fauna of the desert wadies from the paintings and sculptured scenes in the tombs of the Old and Middle Kingdoms and of the Empire. On the walls of many of these tombs are depicted hunting scenes,[4] and among the wild animals figured in them are the lion, leopard, Barbary sheep, wild ass, wild ox, hartebeest, oryx, ibex, addax, dorcas gazelle, fallow deer, giraffe,

[2] Buffon's *Hist. Nat.*, Vol. XII, 1764, p. 24.

[3] Burckhardt, Travels in Nubia, 1819, p. 67.

[4] For a characteristic hunting scene of the Pyramid Age see Borchardt, Grabdenkmal, des Königs Sahure; for one of the Middle Kingdom, Newberry, El Bersheh I, Plate VII.

and ostrich. As several of these animals are not now known in Egypt it has been argued that the scenes do not faithfully represent the ancient fauna of the country. But I can see no reason to doubt that the scenes depict actual hunts that took place in the Arabian and Libyan Deserts not far from the localities in which the tombs figuring them are found. There is some corroborative evidence in the references in the ancient literature to the hunting of the wild animals that frequented Egypt. Thutmose IV., for example, hunted the lion and ibex in the desert plateau near Memphis:[5] Amenhotep III. killed 102 fierce lions during the first ten years of his reign,[6] and in his second regnal year he hunted wild cattle in the desert near Keneh;[6] he saw there a herd of 170, and of these he and his huntsmen captured 96. The desert to the east of Kûft was a famous hunting-ground at the time of the Eighteenth Dynasty. At the present day all but one of the animals represented in these ancient hunting scenes are found in the Nubian Deserts to the south of Egypt. The exception is important; it is the fallow deer which belongs to the Holarctic, not to the Ethiopian, zoological zone. Although most of the animals that were hunted by the dynastic Egyptians have now disappeared from their northern home, many have been recorded in recent years as occurring in the Arabian and Libyan Deserts. We can, in fact, follow them gradually receding southwards. The dorcas gazelle is still common in both deserts, and the addax sometimes occurs in the region of the Wadi Natrûn. The ibex is occasionally seen on the mountains northeast of Keneh. The Barbary sheep (*Ammotragus tragelaphus*) was observed by Dr. Schweinfurth in 1878 in the Wadi Shietun which opens on the Nile below Ekhmim.[7] The wild ass was recorded by James Burton in 1823 in the desert northeast of Keneh; he remarks that then the Arabs of this part of the desert let their female donkeys loose to be served by the wild males.[8] Later, in 1828, Linant de Bellefonds saw many wild asses in the region between Darâwi and Berber; they were, he says, often trapped by the Bisharîn, who used the flesh as food. During the first half of the eighteenth century the ostrich frequented the desert near Suez.[9] A hundred years later it was reported to be numerous in the Arabian Desert opposite Esneh, and there is a wadi, some distance southeast of Aswân, that is called by the Arabs Wadi Naam, "the Wadi of Ostriches." In the Libyan Desert the bird was fairly common in the eighteenth century. W. G. Browne, who traveled along the coast west of Alexandria in 1792,

[5] The Sphinx Stela, 1, 5.
[6] Newberry Scarabs, Plates XXXIII–IV.
[7] Gironale l'Esploratore, anno II, fasc. 4.
[8] Brit. Mus., Add. MS., 25666.
[9] Burckhardt, Travels in Syria, 1822, p. 461.

states that tracks of the ostrich were frequently seen, and he noted also that the bird sometimes appeared in the neighborhood of the Wadi Natrûn.[10] Geoffroy Saint-Hilaire in 1799 reported that it was then common in the mountains southwest of Alexandria.[11] In 1837 Lord Lindsay saw the ostrich near Esneh,[12] but the northern limit of the bird is now very much further south. The lion is mentioned by Sonnini at the end of the eighteenth century as one of the larger carnivora which then approached the confines of Egypt, but did not long remain in the country.

Now the appearance of all these animals in Egypt, and in its bordering deserts in dynastic times presupposes that the vegetation of the wadies was much more abundant then than now, and this again presupposes a greater rainfall than we find at present. The disappearance of the dynastic fauna is not, however, entirely due to the change in climatic conditions. The Arabs have a saying that it was the camel that drove the lion out of Egypt, and this is doubtless true. The lion depends mainly on the antelope tribe for its food supply. The antelopes, on the other hand, depend for their sustenance on herbage and grass, and this has been consumed to a great extent by the camels, which, since Arab times, have been bred in great numbers in the Arabian and Nubian Deserts. It is certain that the advent of the camel was a factor in driving southward many of the wild animals that were at one time so common in Egypt, but are now characteristic of the Ethiopian region.

The characteristic wild trees of the dynastic flora of Egypt, as we know from the remains of them that have been found in the ancient tombs, were the heglik (*Balanites ægytiaca*), the seyal (*Acacia seyal*), the sûnt (*Acacia nilotica*), the tamarisk (*Tamarix nilotica*), the nebak (*Zizyphus spina-Christi*), the sycamore-fig (*Ficus sycomorus*), and the moringa (*Moringa aptera*). The dom palm (*Hyphæne thebaica*) and the Dellach palm (*H. argun*) were also common. The heglik does not now grow wild north of Aswân, and of the other trees, only the sûnt and the tamarisk are really common in the Lower Nile Valley. All these trees, however, now grow in abundance in the region north of the Atbara, and it is here, in what is called the Taka country, that we find also the fauna that was once so abundant in more northerly regions.

But if the fauna and flora of the Arabian and Libyan Deserts in dynastic times approached more closely to that now seen in the Taka country, we have to go further south again for the earliest predynastic fauna and flora of the Lower Nile Valley. This predynastic fauna is particularly interesting, because, in addition to several of

[10] W. G. Browne, Travels in Africa, &c.
[11] Mém. sur l'Egypte, Vol. I, p. 79.
[12] Letters on Egypt, &c., ed. 1866, p. 107.

the animals already mentioned as occurring in dynastic times, we meet with others, such as the elephant,[13] the kudu (*Strepiceros kudu*),[14] the gerenuk gazelle (*Lithocranius walleri*),[15] a species of *Sus*[16] (which is certainly not the wild boar, i. e., *Sus scrofa*), and the marabou stork (*Leptoptilus crumenifer*).[16] From the nature and habits of these mammals and birds it is evident that there must have been a considerable rainfall in the Valley of the Nile north of Aswân when they frequented Egypt. This evidence sanctions the conclusion that a material change in the character of the climate of Northeastern Africa, so far as its rainfall is concerned, has taken place since predynastic days. The flora of the valley of the Lower Nile also points to the same conclusion. Doctor Schweinfurth[17] has drawn attention to the fact that many plants, now known in Egypt only under cultivation, are found in the primeval swamps and forests of the White Nile. He not unreasonably draws the inference that in ages long ago the entire Nile Valley exhibited a vegetation harmonizing in its character throughout much more than at present. The papyrus swamps and reed marshes that lined the Lower Nile Valley in pre-agricultural days have been changed into peaceful fields, in which now grow the cereal grains, wheat and barley, and the other crops that have made Egypt famous as an agricultural country. It was the canalization of the valley, carried out by man, and the consequent draining of the swamps and marshes that displaced the ancient flora from its northern seat, and made it, as at the present day, only to be found hundreds of miles higher up the river. The land of Egypt has, in fact, been drained by man; each foot of ground has been won by the sweat of his brow with difficulty from the swamp, until at last the wild plants and animals which once possessed it have been completely exterminated in it. The agricultural Egypt of modern times is as much a gift of man as it is of the Nile.

I have dwelt at some length on the ancient fauna and flora because I want to bring out as clearly as I can two facts concerning the Egypt of pre-agricultural days—the Egypt of the time before man began to win the alluvial soil for the purposes of agriculture. (1) The aspect of the Lower Nile must have been very different from what it is now; it was a continuous line of papyrus swamps and marshes inhabited by hippopotami, wild boars, crocodiles, and immense flocks of wild fowl of all kinds; it was singularly destitute of trees or plants that could be put to any useful purpose, and timber trees were non-existent; its physical conditions resembled

[13] Journal of Egyptian Archæology, Vol. V, p. 234, Plate XXXIII.
[14] Petrie, Abydos I, Plate L.
[15] Lydekker, Brit. Mus., Guide to the Great Game Animals, 1913, Plate 39, and Figures 21, 22.
[16] Journal of Egyptian Archæology, Vol. V, Plate XXXIII, p. 227.
[17] Schweinfurth, Heart of Africa, Vol. I, p. 69.

those prevailing on the banks of the White Nile to-day. (2) The deserts bordering the Lower Nile Valley on both sides were much more fertile, and their fauna and flora resembled that of the Taka country in Upper Nubia. Of the animals that frequented the wadies only the ass and the wild ox were capable of domestication. If man inhabited Egypt in pre-agricultural times—and there is no valid reason to suppose that he did not—he probably lived a wandering life, partly hunter, partly herdsman, in the fertile wadies that bordered the valley, only going down to the river to fish or to fowl or to hunt the hippopotamus. In the valley itself there was certainly no pasture land for supporting herds of large or small cattle. It was probably also in these wadies that agriculture was first practiced in Egypt. Even at the present day a considerable number of Ababdeh roam the wadies of the Arabian Desert between Keneh and the Red Sea, where, at certain seasons of the year, there is fair pasturage for small flocks of sheep and goats. I have myself seen many of these people in the course of several journeys that I have undertaken to the Red Sea coast. Some of these nomads sow a little barley and millet after a rainstorm, and then pitch their tents for a while till the grain grows, ripens, and can be gathered. They then move on again with their little flocks. What the Ababdeh do on a very small scale, the Hadendoa of the Taka country do on a much greater one.

If we turn to the Taka country we see there people living under much the same physical conditions as those which must have prevailed in the Arabian and Libyan deserts in early times. The inhabitants of the Taka country are Hamite, and, as Professor Seligman has pointed out,[18] the least modified of these people are physically identical with the predynastic Egyptians of Upper Egypt. I would suggest that they, like the fauna and flora of ancient Egypt, receded southward under the pressure of the advance of civilization, and that the physical conditions of the country have preserved them to a great extent in their primitive life and pursuits. The picture of the Taka as Burckhardt draws it would, I believe, describe almost equally well the earliest predynastic Egyptians. This country, called El Gash by its inhabitants, has been described by Burckhardt.[19] In his day the people there were in the transition stage between the pastoral nomad and the agriculturist. It was a fertile and populous region. About the end of June large torrents coming from the south and southwest pour over the country, and in the space of a fortnight or so cover the whole surface with a sheet of water, varying in depth from 2 to 3 feet. These torrents were said to lose themselves in the eastern plain after inundating the

[18] C. G. Seligman, Journal of the Anthropological Institute, Vol. XLIII, p. 595.
[19] Burckhardt, Travels in Nubia, p. 387, et seq.

country, but the waters remained upward of a month in Taka, and on subsiding left a thick slime or mud upon the surface. Immediately after the inundation was imbibed the Bedawîn sowed their seed upon the mud, without any previous preparation whatever. The inundation was usually accompanied by heavy rains, which set in a short time before the inundation, and became most copious during its height. The rains lasted some weeks longer than the inundation; they were not incessant, but fell in heavy showers at short intervals. In the winter and spring the people of Taka obtained their water from deep wells, extremely copious, dispersed all over the country, but at a considerable distance from each other. The people appeared to be ignorant of tillage; they had no regular fields, and the millet, their only grain, was sown among thorny trees. After the harvest was gathered the peasants returned to their pastoral occupations. When Burckhardt visited this region in the hottest part of the year, just before the period of the rains, the ground was quite parched up, and he saw but few cattle; the herds were sent to the Eastern Desert, where they fed in the mountains and fertile valleys, and where springs of water were found. After the inundation they were brought back to the plain. The quantity of cattle, Burckhardt believed, would have been greater than it was had it not been for the wild beasts which inhabited the district and destroyed great numbers of them. The most common of these wild animals were the lion and the leopard. The flocks of the encampment were driven in the evening into the area within the circle of tents, which were themselves surrounded by a thorny inclosure. Great numbers of asses were kept by all these Bedawîn. They also possessed many camels. The trees are described as being full of pigeons. The Hadendoa were the only inhabitants of Taka seen by Burckhardt. Each tribe had a couple of large villages built in the desert on the border of the cultivable soil, where some inhabitants were always to be found, and to which the population, excepting those who tended the cattle in the interior of the desert, repaired during the rainy season. After the waters had subsided they spread over the whole district, pitching their camps in those places where they hoped for the best pasturage, and moved about from month to month, until the sun parched up the herbage. The settlers in the villages meantime sowed the ground adjoining the neighboring desert. The camps consisted of huts formed of mats; there were also a few huts with walls, resembling those in the countries of the Nile, but smaller. Even the settlers, however, preferred living in the open under sheds to inhabiting these close dwellings.

It has often been stated that civilization in Egypt spread from the south, and considerable stress has been laid upon the fact that so many predynastic and early dynastic remains have been found in

Upper Egypt in the region between Edfu and Thinis, especially at Hierakonpolis and Naqada, and north of Naqada, in the neighborhood of Abydos. Opposite Edfu is a desert route leading to the Red Sea; at Kûft, opposite Naqada, is the beginning of the road leading to Kosêr, the port on the Red Sea. It has been thought that the people who brought culture to Egypt reached the Nile Valley by one or by both these routes from a "God's Land" situated somewhere down the Red Sea coast. But throughout the whole history of Egypt culture has always come from the north and spread southward.

From a study of the monuments of the First Dynasty that had been found at Abydos and elsewhere in Upper Egypt I ventured, nearly twenty years ago,[20] to suggest the existence in predynastic times of a Delta civilization which, in culture, was far advanced beyond that of Upper Egypt, and I pointed out that it was probably to a Delta civilization that the dynastic Egyptians owed their system of writing. I was led to this conclusion by the following facts. Although many predynastic cemeteries had been thoroughly explored in Upper Egypt, no grave had yielded a single fragment of hieroglyphic writing. The only inference that can be drawn from this is that hieroglyphic writing was unknown, or at all events unpracticed, by the inhabitants of Upper Egypt before dynastic times. On the other hand, the discoveries at Naqada, Hierakonpolis, and Abydos had shown us that all the essential features of the Egyptian system of writing were fully developed at the beginning of the First Dynasty. Hieroglyphic signs were already in full use as simple phonograms, and their employment as phonetic complements was well established. Determinative signs are found beginning to appear in these early writings, but, as Erman and Griffith have noticed, even as late as the Fifth Dynasty, their use was very restricted in the monumental inscriptions, although they were common in the cursive and freely written texts of the Pyramids. At the very beginning of the First Dynasty the numerical system was complete up to millions, and the Egyptians had already worked out a solar year of 365 days. This was indeed a remarkable achievement.

These facts are of great significance, for it is clear that the hieroglyphic system of writing, as we find it at the beginning of the First Dynasty, must have been the growth of many antecedent ages, and yet no trace of the early stages of its evolution has been found on Upper Egyptian soil. There is no clear evidence, however, that the system was borrowed from any country outside Egypt; the fauna and flora of its characters give it every appearance of being indigenous. It is apparent, therefore, that we must seek the cradle of the Egyp-

[20] Proceedings of the Society of Biblical Archæology, February, 1906, p. 69.

tian system of hieroglypric writing elsewhere than in Upper Egypt, and as the fauna and flora of its characters are distinctly Egyptian the presumption is that it must be located to the Delta. An important indication as to the original home of Egyptian writing is given by the signs which, in historic times, were used to designate the points of the compass. The sign for "east" was a drop-shaped ingot of metal upon a sacred perch, and this was the cult object of a clan living in predynastic times in the Eastern Delta. The sign for "west" was an ostrich feather placed in a semicircular stand, and this was the cult object of the people of the Western Delta. The sign for "south" was a *scirpus* reed; this was the cult object of a clan which dwelt on the east bank of the Nile a little above the modern village of Sharona, in Middle Egypt. The country south of the apex of the Delta was known as *Ta Shema*, "Reed Land." It must, therefore, have been at some point north of the apex of the Delta that the *scirpus* reed was first used to designate the south. It must also have been somewhere in the Central Delta that the cult objects of the peoples of the Eastern and Western Delta were first used to designate "east" and "west."

For the Delta being the early home of writing another fact has to be taken into consideration. Thoth, the Ibis god, was to the Egyptians the god of writing, and it was to him that they attributed its invention. The principal seat of his worship in historic times was Hermopolis, in Middle Egypt. But Thoth's original habitat was situated in the northeast corner of the Delta, where, in predynastic times, had resided an Ibis clan. The tradition that named Thoth as the god and inventor of writing would, therefore, point Deltawards. This tradition is significant also in another way. Although we can not doubt that the Egyptian system of writing was evolved in the Delta, the germs of writing may have come into Egypt from Western Asia *via* this northeast corner of the country. In this connection it may be pointed out that the hieroglyphic signs for "right" and "left" were the same as those for "west" and "east"; the Egyptians who evolved the hieroglyphic system of writing orientated themselves facing south.

It is remarkable that so little is known about the early history of the Delta. But few excavations have been carried out there, and nothing of predynastic, or early dynastic, times, has, so far, been brought to light from the country north of Cairo. We do know, however, that before the arrival of the Falcon kings from Hierakonpolis in the south, Middle and Lower Egypt had been, probably for many centuries, united under one scepter, and that before these two parts of the country were united there had been a Delta Kingdom which had had its capital at Sais. The names of some of these early kings are preserved on the Palermo fragment of the famous Annals Tablet,

and the list there given would alone be enough to prove how ancient the Delta civilization must have been. There was certainly nothing comparable with it in Upper Egypt in those far-off days.

What were the physical conditions prevailing in the Delta and in the regions to the east and west of it immediately preceding Menes' arrival in Lower Egypt? For the eastern side the evidence is exceedingly scanty, but there is one fact which is significant. The chief god of the eastern nomes of the Delta in the Pyramid Age was Anzety, a pastoral deity who was the prototype of Osiris. He is represented as a man holding in one hand the shepherd's crook, and in the other the goatherd's ladanisterion. There can be little doubt, therefore, that in the eastern Delta there lived a pastoral people who possessed flocks of sheep and goats, and this is evidence of a certain amount of grassland. In the Central Delta at the same period there lived a series of clans, among which a Bull Clan was predominant. In historic times in Egypt the ox is often figured roaming in papyrus and reed marshes, and it may be that the Central Delta marshes supported herds of domesticated cattle. Much more is known about the western side of the Delta at the time of Menes. It formed, I believe, part of what was called Tehenu-land, at all events this name was given to the region immediately to the west of the Canopic branch of the Nile. There can be no doubt that this part of the country was a very fertile and prosperous region in the period immediately preceding the First Dynasty. Its name signifies "Olive-land," and we actually see these trees figured, with the name of the country beside them, on a predynastic Slate Palette; on this Palette, above the trees, are shown oxen, asses, and sheep of the type later known as *ser*-sheep. It was Menes,[21] the Falcon King of Upper Egypt, who conquered the people of Tehenu-land. This conquest is recorded on a small ivory cylinder that was found at Hierakonpolis. Another record of the Southerner's triumph over these people is preserved on his famous Slate Palette; here the Upper Egyptian King is depicted smiting their chieftain, while on the verso of the same Palette is the scene of a festival at the Great Port, which was perhaps situated near the Canopic branch of the Nile. The mace head of Menes, which is now in the Ashmolean Museum at Oxford, has a scene carved upon it which shows the king assuming the red crown of Sais, and the inscription accompanying it records that he had captured 120,000 prisoners, 400,000 oxen, and 1,422,000 goats. This immense number of oxen and goats is clear evidence that the northwestern Delta and the region to the west of it (Tehenu-land) must have included within its boundaries

[21] That Narmer was Menes is proved by a sealing published by Petrie in Royal Tombs of the Earliest Dynasties, Plate XIII, 93. His conquest of Tehenu-land is recorded on an ivory cylinder published by Quibell, Hierakonpolis I, Plate XV, 7.

very extensive grasslands. Several centuries after Menes, Sahure, a king of the Fifth Dynasty, captured in Tehenu-land 123,440 oxen, 233,400 asses, 232,413 goats, and 243,688 sheep. Senusret I. also captured in the same region "cattle of all kinds without number." This again shows how fertile the country must have been at the beginning of the Middle Kingdom. The history of this part of the Delta is most obscure. During the period that elapsed from the end of the Third Dynasty to the beginning of the Twenty-third, when Tefnakht appears upon the scene, we have hardly any information about it. What was happening at Sais and other great cities in the northwest of Egypt during the period from 2900 to 720 B. C.? There is an extraordinary lacuna in our knowledge of this part of the country. The people living there were certainly of Libyan descent, for even as late as the time of Herodotus the inhabitants deemed themselves Libyans, not Egyptians; and the Greek historian says that they did not even speak the Egyptian language. The predynastic people who inhabited the greater part of the Lower Nile Valley were apparently of the same stock as these Libyans. There is a certain class of decorated pottery which has been found in predynastic graves from Gizeh in the north to Kostamneh in the south. On this decorated pottery are figured boats with cult-objects raised on poles. Altogether some 170 vases of this type are known, and on them are 300 figures of boats with cult-signs. Of these, 124 give the "Harpoon" ensign; 78 the "Mountain" ensign; and 20 the "Crossed Arrows" ensign. These cult-objects all survived into historic times; the "Harpoon" was the cult-object of the people of the Mareotis Lake region; the "Mountain" and "Crossed Arrows" were the cult-objects of the people dwelling on the right bank of the Canopic branch of the Nile. Thus it will be seen that out of 300 boats figured on vases found in graves in the Lower Nile Valley south of Cairo, 222 belong to cults which can be located in the northwestern corner of the Delta. Twenty-two boats bear the "Tree" ensign, which was the early cult object of the people of Herakleopolis, a city just south of the Fayûm. Ten bear the "Thunderbolt" ensign of Ekhmim. The "Falcon" on a curved perch appears on three boats, and this ensign undoubtedly represents the Falcon deity of Hierakonpolis. At the beginning of the historic period the cult objects of the people of the northwestern Delta included (1) the "Harpoon," (2) the figure-of-eight "Shield with Crossed Arrows," (3) the "Mountain," and probably (4) the "Double Axe," [22] and (5) a "Dove or Swallow." [22] With the exception of the "Harpoon" all these cult objects are also found in Crete, a fact which is significant in view of Sir Arthur

[22] The Cults of the Double Axe and of the Dove or Swallow are found on monuments of the Pyramid Age.

Evans's remark, quoted at the beginning of my address, to the effect that he considers the possibility of some actual immigration into the island of the older Egyptian element due to the first Pharaohs. The "Harpoon," it should be noted, is the prototype of the bident, and later, of the trident of the Libyan god Poseidon.

Upon the mace-head of Menes, the king is represented assuming the crown of Neith of Sais. This is the earliest representation of the famous Sed festival which is generally held to be a survival, in a much weakened form, of the ceremonial killing of the king, its essential feature being regarded as the identification of the king with the god Osiris. The festival was, I believe, of Libyan origin, and, at all events in its origin, it was not connected in any way with Osiris. On this mace-head the Upper Egyptian conqueror is shown seated under a canopy upon a daïs raised high above the ground. He is clad in a long, close-fitting garment; upon his head is the red crown of Sais, and in one of his hands is the so-called flail. Behind him is a group of officials, and upon either side of the daïs are two fan bearers. In front of the king is a princess seated in a palanquin, and behind her are three men figured in the act of running. This is the earliest of a long series of representations of the festival, and we can not doubt that the particular ceremony here depicted was the central one around which, in later times, the other ceremonies that we know were connected with it were grouped. There is no indication here of any ceremonial killing of the king, and the red crown which Menes wears is not characteristic of Osiris but of the goddess Neith of Sais. In the Mortuary Temple of Neuserre at Abusir, in the Temple of Amenhotep III, at Soleb in Nubia, and in the Temple of Osorkon III, at Bubastis, the Sed festival is represented in far greater detail, but still there is no indication of the ceremonial killing of the king, or of his identification with Osiris. These later scenes show that the festival was a great national one that was attended by all the great dignitaries of state, and by the priests of the gods from all the principal cities of Egypt. In these later representations the king's daughters and the running men play an important part. Inscriptions accompanying the scenes at Soleb[23] and Bubastis state that the king at this festival assumed the protection of Egypt and of the sacred women of the Temple of Amon. The Queen at these periods of Egyptian history was the High Priestess of Amon and the Head of the Harîm of the god. An important reference to the festival is found in the inscription of Piankhy. This Ethiopian king, in his triumphant march from Thebes toward the Delta, had captured Hermopolis, the capital of a petty king named Namlot (a Libyan Dynast), and when Piankhy made his entry into the city he was

[23] I owe my knowledge of the greater part of the Soleb scenes to Prof. Breasted, who kindly showed me unpublished drawings of them when I visited him in Chicago in 1921.

acclaimed by the people, who prayed that he would celebrate there a Sed festival. "His Majesty proceeded to the palace of Namlot, and entered every chamber. He caused that there be brought to him the king's wives and the king's daughters. They saluted His Majesty in the fashion of women," but the Ethiopian says that he would not turn his face to them, and he did not celebrate a Sed festival. The most important point in connection with the festival is that at it the king assumed the protection of the land of Egypt. It was a kind of coronation festival. On Menes's mace head the king is shown assuming the red crown, while before him is the princess of the country that he had conquered, and below her is a statement of the number of prisoners and cattle captured by him in her country.

Now what were the rules that regulated the succession to the kingship in Ancient Egypt? It is often assumed that the kingship was hereditary in the male line, and that the son regularly succeeded his father on the throne. But we know that many Egyptian kings were not the sons of their predecessors. We also know that at some periods, at all events, the sovereign based his claim to the kingship upon the fact that he had married the hereditary princess. Harmhab, at the beginning of the Nineteenth Dynasty, tells us that he proceeded to the palace at Thebes, and there, in the Great House (*pr-wr*), married the hereditary princess. Then the gods, "the lords of the House of Flame (*pr-nsrt*), were in exultation because of his coronation, and they prayed Amon that he would grant to Harmhab the Sed festivals of Re." It was after his marriage to the princess that Harmhab's titulary was fixed. The reference to the House of Flame is interesting because the kindling of fire was an important ceremony at the Sed festival; it is figured at Soleb, and there a priestess called "the Divine Mother of Suit" plays an important rôle. This priestess may be compared with Vesta, who always bore the official title of "Mother," never that of "Virgin." It is unnecessary for me to speak of the King's fire and the vestal virgins whose duty it was to keep the perpetual fire burning; the material has been collected by Sir James Frazer. This ceremony of kindling fire suggests that the festival may have been a marriage festival, and the running men figured on the mace head of Menes, and in later representations, also points to this interpretation of it. There can be little doubt that it was a Libyan festival; at all events it is first found when Menes assumed the red crown of Neith of Sais. When Menes had conquered the northwestern Delta, he married the hereditary princess of the country. She was probably the eldest daughter, or perhaps the widow, of the Lower Egyptian king whose country he had seized. Marriage with the king's widow or eldest daughter carried the throne with it as a matter of right, and Menes's marriage,

we can well believe, was a marriage of policy in order to clinch by a legal measure his claim to that crown which he had already won for himself in battle. Sir James Frazer has noted that sometimes apparently the right to the hand of the princess and to the throne has been determined by a race. The Libyan king Antæus placed his daughter Barce at the end of a race course; her noble suitors, both Libyans and foreigners, ran to her as the goal, and the one who touched her first gained her in marriage. The Alitemnian Libyans awarded the kingdom to the fleetest runner. According to tradition, the earliest games at Olympia were held by Endymion, who set his sons to run a race for the kingdom. In all the ceremonies connected with the Sed festival I can see no feature that suggests the Osirification of the king. When he wears the red crown he assumes control of Lower Egypt; when he wears the white crown he assumes control of Upper Egypt. There is one further point connected with the western side of the Delta that must be noted. Glazeware (and glass) in Egyptian is called *tehent;* this was one of the chief articles of export of Tehenu-land. Just as we use the word "china" for a kind of porcelain which first came to us from China, so the Egyptians called glass *thn.t* after the country of the northwestern Delta from which they derived it. Here in this western side of Lower Egypt is an almost wholly unexplored field for the anthropologist.

I have already referred to the pastoral deity Anzety, who, in the Pyramid Age, was chief of the nomes of the Eastern Delta. Among all the nome gods he is the only one that is figured in human form; he stands erect holding in his right hand the shepherd's crook and in his left the goatherd's ladanisterion. On his head is a bicornate object that is connected with goats, and on his chin is a false beard curled at the tip. He was not an ox herd, but a shepherd and goatherd. In later times, the figure of this deity, in hieroglyphic writing, is regularly used as the determinative sign of the word *ity*, "ruling prince," "sovereign," a term that is only applied to the living king. In the Pyramid texts, Anzety is entitled "Head of the Eastern nomes," and these included the ancient one of the Oxyrrhynchus fish, where, later, the ram or goat was the chief cult animal. Neither the domesticated sheep nor the goat can be reckoned as Egyptian in origin; they both came into Egypt from Western Asia. We have, therefore, in this pastoral deity Anzety evidence of immigration from the west. The only wild sheep inhabiting the continent of Africa is the Barbary sheep, and this animal was not the ancestor of any domesticated breed. Both the sheep and the goat are essentially mountain animals, though sheep in the wild state do not as a rule frequent such rugged and precipitous ground as their near relatives the goats, but prefer more open country. Sheep browse in short grass; goats feed upon the

young shoots of shrubs and trees. The domesticated goat is generally recognized as descended from the wild goat (*Capra hircus ægagrus*) of Syria, Asia Minor, Persia, and the Mediterranean Isles. Two breeds of domesticated sheep were known to the Egyptians. The sheep of the earliest historical period down to the Middle Kingdom was a long-legged variety (*Ovis longipes*), with horns projecting transversely and twisted. This breed was the only one known in the earlier periods of Egyptian history; it was the predominant breed in the Middle Kingdom, but soon after the beginning of the Empire it appears to have become rare or extinct in Egypt, and was superseded by a variety with horns curving forwards in a subcircular coil. Both varieties of domesticated sheep, according to Lydekker, were introduced into Egypt through Syria.

Among the cult-objects of the cities over which the god Anzety presided were two, which, I believe, can definitely be referred to trees that were not indigenous to the soil of Egypt but to Syria. One of these cult objects is the so-called "Ded column." This was one of the holiest symbols of the Egyptian religion. It has four crossbars at the top like superposed capitals. Sometimes a pair of human eyes are shown upon it, and the pillar is draped; sometimes a human form is given to it by carving a grotesque face on it, robing the lower part, crowning the top with ram's horns, and adding two arms, the hands holding the crook and ladanisterion. Frazer has suggested that this object might very well be a conventional representation of a tree stripped of its leaves. That it was, in fact, a lopped tree is, I believe, certain. In the Pyramid texts it is said of Osiris, "Thou receivest thy two oars, the one of juniper (*uan*), the other of *sd*-wood, and thou ferriest over the Great Green Sea." The determinative sign of the word *sd* is a tree of precisely the same form as the Ded column that is figured on early Egyptian monuments, i. e., it has a long, thin stem. This tree-name only occurs in inscriptions of the Pyramid Age, and it is mentioned as a wood that was used for making chairs, tables, boxes, and various other articles of furniture. In the passage quoted from the Pyramid texts it is mentioned together with juniper, and the latter was employed in cabinet-making, etc., at all periods of Egyptian history. There is no evidence that juniper ever grew in Egypt, but we have numerous records of the wood being imported from the Lebanon region. The *sd*-tree, as we see from the determinative sign of the name, had horizontally spreading branches, and was evidently some species of conifer. No conifers, however, are known from Egypt; the *sd*-wood must, therefore, have been of foreign importation. As it is mentioned with juniper, which we know came to Egypt from Syria, it is possible that it came from the same region. Among the trees of the Lebanon there are four that have hori-

zontally spreading branches. These are the cedar (*Cedrus libani*), the Cilician fir, the *Pinus laricio*, and the horizontal-branched cypress (*Cupressus sempervirens* var. *horizontales*). Much misconception at present exists with regard to the Lebanon cedar, because the name "cedar" is applied to a large number of woods which are quite distinct from it, and the wood which we generally call cedar (e. g., the cedar of our "cedar" pencils) is not true cedar at all, but Virginian juniper. The wood of *Cedrus libani* is light and spongy, of a reddish-white color, very apt to shrink and warp badly, by no means durable, and in no sense is it valuable. Sir Joseph Hooker, who visited the Lebanon in 1860, notes that the lower slopes of that mountain region bordering the sea were covered with magnificient forests of pine, juniper, and cypress, "so that there was little inducement for the timber hewers of ancient times to ascend 6,000 feet through 20 miles of a rocky mountain valley to obtain cedar wood which had no particular quality to recommend it. The cypress, pine, and tall, fragrant juniper of the Lebanon, with its fine red heartwood, would have been far more prized on every account than the cedar." The *sd*-tree was, I believe, the horizontal-branched cypress which is common in the wild state. In the Middle Ages this tree was believed to be the male tree, while the tapering conical-shaped cypress was considered to be the female. This is an interesting fact, because there is some evidence to show that the tapering variety was the symbol of Hathor-Isis, while the horizontal-branched one was the symbol of Osiris.

In the Pyramid Age there are several records of the priests of the Ded column. They were called "priests of the venerable Ded column." The seat of the cult was Dedu, or, as it was sometimes called, *Pr-Wsr*, "the House of Osiris," the Greek Busiris in the Central Delta. At this city was celebrated annually a great festival in honor of Osiris. It lasted many days, and the culmination of a long series of ceremonies was the raising of the Ded column into an erect position. Osiris is intimately connected with this column; the Egyptians called it his backbone. In the myth of Osiris, as recorded by Plutarch, a pillar played an important part. Plutarch says that the coffer containing the body of Osiris was washed up by the sea at Byblos, the port of the Lebanon, and that a tree grew up and concealed the coffin within itself. This sacred tree was cut down by Isis and presented to the people of Byblos wrapped in a linen cloth, and anointed with myrrh like a corpse. It therefore represented the dead god, and this dead god was Osiris.

Not far from Dedu, the city of Osiris in the Delta, was Hebyt, the modern Behbeyt el Hagar. Its sacred name was Neter. The Romans called it Iseum, or Isidis oppidum. It was the ancient seat of Isis worship in Egypt, and the ruins of its temple to that goddess

still cover several acres of ground in the neighborhood. On the analogy of other sacred names of cities the primitive cult-object here was the *ntr*-pole. This was not an axe as has so often been supposed, but a pole that was wrapped around with a band of colored cloth, tied with cord halfway up the stem, with the upper part of the band projecting as a flap at top. Dr. Griffith conjectured that it was a fetish, e. g., a bone carefully wound round with cloth, but he noted that "this idea is not as yet supported by any ascertained facts." As a hieroglyph this wrapped-up pole expresses *ntr*, "god," "divine," in which sense it is very common from the earliest times; gradually it became determinative of divinity and of the divine names and ideographic of divinity. Another common ideograph of "god" in the Old Kingdom was the Falcon (Horus) upon a perch, and this sign was also employed as a determinative of divinity and of the names of individual gods; it even sometimes occurs as a determinative sign of the *ntr*-pole, e. g. Pyramid Texts, 482. This use of the Falcon indicates that in the early dynasties the influence of the Upper Egyptian Falcon god (Horus) was paramount. But there is reason for believing that the *ntr*-pole cult had at an earlier period been the predominant one among the writing people of the Delta; this, I think, is shown by the invariable use of the *ntr*-pole sign in the words for priest (*hm-ntr*, "god's servant"), and temple (*ht-ntr*, "god's house"). Now, on a label of King Aha of the First Dynasty there is a representation of the temple of Neith of Sais. Here two poles with triangular flags at top are shown on either side of the entrance. Later figures of the same temple show these poles with the rectangular flags precisely as we find in the *ntr*-sign. A figure of the temple of Hershef on the Palermo Stone shows two poles with triangular flags, while a Fourth Dynasty drawing of the same temple shows the same poles with rectangular flags. We see, therefore, that the triangular-flagged pole equals the rectangular-flagged one, and that the *ntr* is really a pole or mast with flag. Poles of this kind were probably planted before the entrances to most early Egyptian temples, and the great flag masts set up before the pylons of the great temples of the Eighteenth and later dynasties are obviously survivals of the earlier poles. The height and straightness of these poles prove that they can not have been produced by any native Egyptian tree; in the Empire flag staves were regularly imported from Syria; it is probable therefore that in the earlier times they were introduced from the same source. A well-known name for Syria and the east coast of the Red Sea, as well as of Punt, was Ta-ntr, "the land of the *ntr*-pole." This was the region in which the primitive Semitic goddess Astarte was worshipped. In Canaan there was a goddess Ashera whose idol or symbol was the ashera pole. The names of Baal and Ashera are sometimes coupled pre-

cisely as those of Baal and Astarte, and many scholars have inferred that Ashera was only another name of the great Semitic goddess Astarte. The ashera pole was an object of worship, for the prophets put it on the same line with the sacred symbols, such as Baal pillars; the ashera was, therefore, a sacred symbol, the seat of a deity, the mark of a divine presence. In late times these asherîm did not exclusively belong to any one deity; they were erected to Baal as well as to Yahw. They were signposts set up to mark sacred places, and they were, moreover, draped. They correspond exactly to the *ntr*-poles of Egyptian historic times. I have noted that these *ntr*-poles were tall and straight. What tree produced them? In Egyptian inscriptions there is often mentioned a tree named *tr.t.* It was occasionally planted in ancient Egyptian gardens, and specimens of it were to be seen in the Temple garden at Heliopolis. The seeds and sawdust were employed in medicine, and its resin was one of the ingredients of the Kyphi-incense. Chaplets were made of its twigs and leaves. The tree was sacred to Hathor; branches of it were offered by the Egyptian kings to that goddess. In a Saite text it is mentioned with three other trees—pine, yew, and juniper; these are all found in Northern Syria, where they grow together with the cypress; the *tr.t* tree may therefore be the cypress. Evidence has been brought forward to show that the *sd*-tree is the horizontal-branched cypress, which was believed to be a male tree, while the tapering, flame-shaped cypress was believed to be the female tree. The Ded column was the symbol of Osiris, and at Busiris was celebrated a festival of raising this column. The *tr.t* tree was sacred to Hathor, who is often identified with Isis, and there was a festival of raising the *tr.t* tree that was celebrated on the nineteenth day of the first month of the winter season. It is not known where this festival was celebrated, but it may well have been at Neter, the seat of the Isis cult near Dedu-Busiris. The two tree-cults point to Northern Syria as the country of their origin.

In the architecture of ancient Egypt two distinct styles can be recognized. One is founded on wattle-and-daub, the other on wood construction. Wattle-and-daub is the natural building material of the Nile Valley and Delta, and the architectural forms derived from it are certainly indigenous. Those styles derived from wood construction, on the other hand, could not have originated in Egypt, but must have arisen in a country where the necessary timber was ready at hand. Egypt produces no coniferous trees and no timber that is at all suitable for building purposes, or indeed for carpenter's work of any description. The wood of the sycamore fig is very coarse-grained, and no straight planks can be cut from it. The sûnt-acacia is so hard that it requires to be sawn while it is green; it is very

irregular in texture, and on account of the numerous branches of the trunk it is impossible to cut it into boards more than a couple of feet in length. The palaces of the early kings of the Delta were built of coniferous wood hung with tapestry-woven mats. The tomb of Menes' queen, Neith-hotep, at Naqada, was built of brick in imitation of one of these timber-constructed palaces, and smaller tombs of the same kind are known from the Second and Third Dynasties, but not later. As early as the reign of King Den (First Dynasty) the palaces of this type were beginning to be built of the native wattle-and-daub in combination with wood, and by the end of the Pyramid Age the style disappears entirely, though the memory of it was preserved in the false doors of the tombs and stelæ. Brick buildings similar to those of the "palace" style of Egypt are also known from early Babylonia, and they were at one time regarded as peculiarly characteristic of Sumerian architecture. These, obviously, must have been copied, like the Egyptian, from earlier timber forms. In Babylonia, as in Egypt, timber was scarce, and there are records that it was sometimes obtained from the coast of Syria. This was the region from which the Egyptians throughout historic times obtained their main supplies of wood, so it is not improbable that they, as well as the Sumerians, derived this particular style of architecture from Northern Syria. I may observe in passing that in this "palace" style we have the transition form between the nomad's tent and the permanent building of a settled people. The lack of native timber in Egypt is significant in another direction. Boats of considerable size are figured on many predynastic monuments. They are long and narrow, and in the middle there is usually figured a reed or wicker-work cabin. In my view these boats were built, like many of those of later periods in Egypt, of bundles of papyrus reeds bound together with cord; they were, in fact, great canoes, and, of course, were only for river traffic. They were not sailing boats, but were propelled by means of oars. No mast is ever figured with them, but they generally have a short pole amidships which is surmounted by a cult-object. On one predynastic vase there is a figure of a sailing ship, but this is totally different in build from the canoes, and it has a very high bow and stern with its mast set far forward in the hull. Similar vessels are figured on the ivory knife handle of predynastic date from Gebel el Araq, but these vessels appear to be in port and the sails are evidently lowered. I have already referred to the Great Port mentioned on the Palette of Menes. A port implies shipping and trade relations with people dwelling along the coast or across the sea. It may be that the people of the northwestern Delta built wooden ships, but if they did they must have procured their timber from some foreign source. Coniferous wood was already being imported into the Nile Valley at the beginning of the First Dynasty

from the Lebanon region, and it must be remembered that the Egyptian name for a seagoing ship, was *kbnyt*, from *Keben*, "Byblos," the port of the Lebanon, where these ships must have been built and from whence they sailed. The sacred barks of the principal gods of Egypt in historic times were invariably built of coniferous wood from the Lebanon. Transport ships on the Nile were sometimes built of the native sûnt wood, and Herodotus describes them as made of planks about 2 cubits long which were put together "brick fashion." No masts or sail-yards, however, could possibly be cut from any native Egyptian tree. In the Sudan at the present day masts are sometimes made by splicing together a number of small pieces of sûnt and binding them with oxhide, but such masts are extremely liable to start in any gale, and they would be useless for seagoing ships. It may be doubted whether the art of building seagoing ships originated in Egypt. It may be doubted also whether the custom of burying the dead in wooden coffins originated in Egypt. In countries where a tree is a rarity a plank for a coffin is generally unknown. In the Admonitions of an Egyptian Sage, written some time before 2000 B. C., at a period when there was internal strife in Egypt, the sage laments that "Men do not sail northward to [Byb]-los[24] to-day. What shall we do for coniferous trees[25] for our mummies, with the produce of which priests are buried, and with the oil of which [chiefs] are embalmed as far as Keftiu? They come no more." This ancient sage raises another anthropological question when he refers to the oil used for embalming. The only oils produced by native trees or shrubs in Egypt were olive oil, ben oil from the moringa, and castor oil from the castor-oil plant. The resins and oils used for embalming were principally those derived from pines and other coniferous trees. Egypt produced no kinds of incense trees or shrubs. The common incenses were pine resin, ladanum, and myrrh, and all these were imported. It is difficult to believe that the ceremonial use of incense arose in Egypt.

These are a few of the questions raised by a study of the material relating to the origins of the ancient civilization of Egypt. There are numbers of others that are waiting to be dealt with. Egypt is extraordinarily rich in material for the anthropologist. It is a storehouse full of the remains of man's industry from pre-agricultural times right down to the present day. Almost every foot of ground hides some relic of bygone man. The climatic conditions prevailing there are exceptional, and it is largely owing to the absence of rain that so full a record of man and his works has been

[24] This place ends *-ny;* the restoration [*Kp-*]*ny* is due to Sethe and "suits the traces, the space, and context quite admirably."—A. H. Gardiner, The Admonitions of an Egyptian Sage, Leipzig, 1909, p. 33.

[25] The word is *as*, as generic one for pines, fir, etc.

preserved. For more than a century excavators have been busy in many parts of the country, but there is yet no sign that the soil is becoming exhausted; it is, in fact, almost daily yielding up its buried treasures. The past two or three decades have been prolific in surprises. Mines of hidden wealth have been unearthed where but a few years ago we only saw the sands and rocky defiles of the desert. Since we met at Hull last year, the most sensational archeological discovery of modern times has been made in a place that had been abandoned by many excavators as exhausted. This discovery, due to the untiring persistence of an Englishman, promises to yield results of extraordinary interest, but it will take years before they can be adequately published. Other discoveries have been made in Egypt during recent years which have opened out a vista of human history that we little dreamt of a quarter of a century ago. Three decades ago not a single monument was known that could be ascribed with certainty to the period before the Third Egyptian Dynasty. To-day we possess a continuous series of written documents which carry us back to Menes, the founder of the Monarchy, some 3,400 years or more before our era. These written documents, moreover, show clearly that Menes himself must have come at the end of a very long period of development. Egypt had already had a long history when the upper and lower countries were first united under a single sceptre. From Upper Egypt we possess a continuous series of uninscribed monuments which take us back far into prehistoric times. An immense vista has been opened out before our eyes by the discoveries of the last thirty years, and now, in Egypt better than in any other country in the world, we can see man passing from the primitive hunter to the pastoral nomad, from the pastoral nomad to the agriculturalist, and then on to the civilized life which begins with the art of writing. We can see in the Delta and in the Lower Nile Valley tribes becoming permanently settled in fixed abodes around primitive cult centers, and then uniting with others into one community. We can trace the fusion of several communities into single States, and then, later, the uniting of States under a supreme sovereign. What other country in the world preserves such a record of its early history?

I have but little time left to speak of the modern Egyptians, but to the anthropologist few people are more interesting. In almost every circumstance of daily life we see the old in the new. Most of the ceremonies from birth to burial are not Muslim, or Christian, or Roman, or Greek; they are ancient Egyptian. In the transition of a people from one religion to another the important institutions of the older doctrine are generally completely abolished; many ceremonies and much unessential detail, however, survive, and in the Delta and

Lower Nile Valley survivals are extraordinarily numerous. It was Lady Duff Gordon who said that Egypt is a palimpsest in which the Bible is written over Herodotus, and the Koran over that; the ancient writing is still legible through all. There is a passage in one of her letters which describes her visit to some Nubian women. Their dress and ornaments were the same as those represented in the ancient tomb paintings. Their hair was arranged in little plaits, finished off with lumps of yellow clay burnished like golden tags. In their house Lady Duff Gordon sat on a couch of ancient Egyptian design, with a semicircular headrest. They brought her dates in a basket such as you may see in the British Museum. So closely did they and their surroundings resemble the scenes of the ancient tombs that she says she felt inclined to ask them how many thousand years old they were! The modern worship of the people is full of the ancient; many of the sacred animals and trees have taken service with Muslim saints. Up to a few years ago cats were still fed by the "Servant of Cats" in the Kadi's court in Cairo. Cobras are still held in great reverence in the city of the Khalifs. Some time ago the director of the Zoological Gardens in Cairo told me that it was most difficult to procure cobras for the gardens. It was not because they were scarce, but because the demand for them was so great that the price asked was far more than the Government would pay. Many cobras, I was told, were kept in the upper rooms of houses in the native quarters of the city. The funeral customs of the people throughout the country are much the same as those which prevailed in ancient times. It is not only among the merchant and agricultural classes that we find the Old in the New. Mrs. Poole, the sister of the Arabic scholar Edward Lane, writing from Cairo in 1846, describes the scenes in one of Mohammed Ali's palaces on the death of a princess of the royal family. Immediately the royal lady breathed her last, her relations and slaves broke up all the beautiful china and glass which had been her property. "The destruction after a death," Mrs. Poole remarks, "is generally proportioned to the possessions of the deceased; therefore, in this case, it was very extensive." Many, perhaps most, of the festivals of the country are of ancient origin. In the Delta towns and villages there are several which are similar to those that were held there in ancient days. It is the same in Upper Egypt. Thebes still possesses its sacred boat, and on the festival commemorating the birthday of Luxor's patron saint, Abu'l Haggag, this lineal descendant of the sacred bark of Amon decorated with flags and gaily colored bits of cloth, is drawn around the town in procession, amid the acclamations of the people. Modern Egypt has hardly been touched by the anthropologist. The Government official usually holds him-

self far too aloof to ever really get into intimate contact with the native. Edward Lane did much to record the manners and customs of the Cairene Egyptian, but he never lived among the fellahîn, and his book contains little about the modern dweller on the banks of the Nile outside Cairo. A rich harvest awaits any student who, knowing the language, will settle and live throughout the year among the peasants in any village or town in the Lower Nile Valley or Delta. It is only in this way that a real knowledge of the people can be obtained. Far less is known about them than about many a tribe in Central Africa.

Thucydides, in the preface to his "History," proposed to record past facts as a basis of rational provision in regard to the future, but he was not the first to whom this great thought had occurred. A thousand years before the Greek historian was born an old vizier of Egypt said of himself that he was "skilled in the ways of the past," and that "the things of yesterday" caused him "to know tomorrow." Anthropology, the science of man and civilization, aims at discovering the general laws which have governed human history in the past and may be expected to regulate it in the future. The Egyptian vizier had, at most, a couple of thousand years of recorded history before him. Since his time the area of history has been ever widening, and we ourselves can look back over nearly six thousand years of human endeavor. We know considerably more of the past than did our forefathers, and though those who hold the reins of government do not usually learn by experience, the anthropologist ought to be able to predict a little better than the politician about the future. For thousands of years Egypt has been under foreign rule. It has been under the yoke of Ethiopian and Persian kings, under the Greek and Roman, Arab and Ottoman conquerors. Its people suffered three thousand years of oppression. For the last forty years it has had English justice. Egypt has this year been handed back to the Egyptians. It is an Oriental country. What will be the immediate future of its people? It is not difficult to predict. Seventy years ago, when Egypt was under the sway of Said Pasha, there was current among the fellahîn of Thebes a little parable, and with this I will conclude. I quote it as it was taken down by Rhind in the fifties of last century, but the story was still remembered when I lived among the natives of Upper Egypt twenty-eight years ago. It runs thus:

"It happened once that a sultan captured a lion, which it pleased him to keep for his royal pleasure. An officer was appointed especially to have in charge the well-being of the beast, for whose sustenance the command of His Highness allotted the daily allowance of 6 pounds of meat. It instantly occurred to the keeper that

no one would be a bit the wiser if he were to feed his dumb ward with 4 pounds and dispose of the remaining two for his own benefit. This he did, until the lion gradually lost his sleekness and vigor, so as to attract the attention of his royal master. 'There must be something wrong,' said he; 'I shall appoint a superior officer to make sure that the former faithfully does his duty.' No sooner was the plan adopted than the first goes to his new overseer, and convincing him very readily that if the proceeds of 2 pounds be conveyed to their pockets, the meat would be far better employed than in feeding the lion, they agreed to keep their own counsel and share the profit between them. But the thirst of the newcomer soon becomes pleasantly excited by the sweets of peculation. He talks the matter over with his subordinate, and they have no difficulty in discovering that the lion might very well be reduced to 3 pounds a day. Drooping and emaciated, the poor beast pines in his cage, and the sultan is more perplexed than before. 'A third official shall be ordered,' he declares, 'to inspect the other two'; and so it was. But they only wait for his first visit to demonstrate to him the folly of throwing away the whole 6 pounds of meat upon the lion, when with so little trouble they could retain 3, 1 apiece, for themselves. In turn his appetite is quickened and he sees no reason why 4 pounds should not be abstracted from his ward's allowance. The brute, he states to his colleagues, can do very well on 2, and if not, he can speak to nobody in complaint, so why need they lose the gain? And thus the lion, reduced to starvation point, languishes on, robbed and preyed upon by the overseers set to care for him, whose multiplication has but added to his miseries."

NORTH AMERICAN INDIAN DWELLINGS[1]

By T. T. Waterman

Museo Nacional, Guatemala

[With 11 plates]

The Indians of North America occupied an enormous area, in which they encountered almost every known variety of climate and scenery. In the various regions accordingly there were evolved different ways of living and, especially, different forms of dwellings. The forms of Indian habitations were affected by climate and were modified according to materials available and house types of different regions accordingly offer marked contrasts. Some were simple; so simple that nothing could be more startlingly primitive (see the Paiute village shown below, pl. 11, fig. 2). Some were very complex, and hundreds of feet in length. Some were made of tremendous beams in a cyclopean style of carpentry, while in at least one area stone masonry was developed, and the ruins of the ancient stone structures are imposing even to-day (see, for example, Pueblo Bonito, pl. 7). Some Indian dwellings are picturesque, some are odd, and all are interesting. The way in which geographic forces operated in shaping or modifying the habitations of the Indian tribes is an interesting matter for investigation. The subject may well be introduced by glancing at two habitation types, both important and characteristic but very different, the wigwam and the tipi.

THE WIGWAM

The word "wigwam," in the language of the Algonkian-speaking peoples of the Atlantic side of the continent, means simply a dwelling. The term was applied by Europeans to the types of structures they encountered among the tribes of the middle Atlantic states. These habitations were essentially permanent structures and were grouped into regular towns, with squares and public buildings, which were fortified, and in many cases defended with earthworks. Mov-

[1] Reprinted by permission from The Geographical Review, Vol. XIV, No. 1, January, 1924.

able tents were not in use in this region; and the wigwam is not by any means a tent. It was not essentially a conical lodge, like those used farther west, but it had in most cases an arched-over roof or was hemispherical. The simpler forms were shaped like half an orange, but the vast majority were elongate. The Sac and Fox Indians, to mention no others, live in this type of dwelling even to-day. The wigwam in many cases had room enough to accommodate a large number of families and would contain, in addition to benches and sleeping platforms, space for a year's supply of food.

The eastern Indians who used this form of dwelling were by no means nomadic savages as often pictured, living by plunder and the chase. They were peaceable farmers, when circumstances allowed them to be, living on products quite familiar on our own tables, corn bread, squashes, plums, wild grapes, berries, maple sugar, and meat when obtainable. The settler on the Atlantic seaboard got his food plants, his maple sugar, and his custom of holding "husking bees," directly from the Indian.

This settled, agricultural mode of life together with the wigwam was distributed over a large part of eastern North America. Briefly, it went wherever the rainfall and the temperature permitted cultivation of maize. This plant grows naturally only where the hot growing season is accompanied by rains. Everyone who has crossed the continent has been struck by the change in the face of nature in the region of the one hundredth meridian, the longitude of central Kansas. Westward lies the region of dry as contrasted with rainy summers. Corn can be grown in the drier west only with artificial irrigation. Wigwams and the easy cultivation of maize go together and are characteristic of eastern North America.

The aborigines in this eastern area being sedentary in the same sense as the present population is, it follows that their houses would be permanent, not movable. The house structure consisted of a framework of poles, planted solidly in the ground and bent over to form arches, covered in with some light material. The construction was practically determined in advance by the nature of the forest, for the trees consisted in large part of hard woods, which could not readily be worked up by primitive implements. The material used to cover the house was of considerable variety. In the Atlantic region the most popular covering was bark, which was readily available, both in large quantities and in large pieces, from a variety of trees, among them birch, elm, hickory, and ash. In areas where large sheets of bark could not readily be obtained, other materials were substituted. Thus, beyond the westward margin of the forested area, on the plains of Arkansas, houses of a similar framework of poles were thatched over with grass, as among the Wichita (see pl.

4, fig. 1). Among the Ojibwa and Menominee, in the lake region of Minnesota, matting made of rushes was employed as covering material, being more readily available there than bark. It is noteworthy in a general way that as we go farther north Indian houses become simpler and simpler, until in the far north, among the Cree or the Salteaux, the structure is a simple framework of light poles in the shape of a flat cone, covered over in some fashion with sheets of bark matting, or what not.

The original population in this eastern area was dense as compared with that farther west, because of the greater productivity based in turn on the occurrence of summer rains. There were people enough, for instance, to build numerous and quite substantial earthworks. These included burial mounds, ceremonial mounds, and fortifications. The mounds were so widely scattered and some at least of the fortifications so tremendous and impressive, that we have come to refer to these peoples as "mound builders." The idea that the mound builders were different in any respect from other Indians is quite without foundation. Some of the mounds were built, in fact, after the coming of the whites, as is proved by the presence in them of European objects—medals, scissors, porcelain, pewter, metal buttons, and iron knives. Yet all the Indians living in the Ohio Valley at the moment when the settlers came into that region were not numerous enough to man the ramparts of the old Indian earthwork known as "Fort Ancient." This decline may be attributed to a sudden movement of the erstwhile stationary population from the area, owing probably to the introduction into America of the horse. The Indians were originally without horses and, in North America and Mexico, without burden animals of any description except the dog. In fact, American Indian society, speaking generally, developed a civilization without draft animals or vehicles. The introduction of the horse by the Spaniards led to a great economic transformation, a general drift of the population to the Plains, where pursuit of the buffalo was suddenly made very easy and sensationally successful. Here a peculiar way of living developed, apparently after the Spanish conquest of Mexico but long before the inroad of English-speaking people from the Atlantic side. Let us turn to the habitations of the "horseback" Indians of the Plains.

DWELLING OF THE PLAINS INDIANS: THE TIPI

The history of the Plains region of North America does not go back very far. When our historical knowledge begins, the tribes were already in possession of horses, and a novel mode of existence had already developed. What conditions had been before that time

we can only surmise from a few survivals and from archeological evidence obtained in the old sites. Some very quaint and curious information has recently been brought to light in the latter way. What we consider the typical mode of existence of the Plains Indians is therefore only the latest phase of their mode of life and a very novel and highly modified phase at that. Moreover, as we have already remarked, this highly modified mode of existence has commonly come to be considered as the mode of life typical not only of the Plains Indians but of all Indians. The appearance, dwellings, and even costume of the modern Indian of the Plains is what comes to mind when anyone says "Indian."

Physically the Plains Indians were, and are, a very fine people, possessing the gift of wearing costume strikingly. This trait is shared by men and women. The war bonnet of eagle feathers, worn by the men and never by women (the Indian woman on the old-style United States copper penny to the contrary notwithstanding), is the most picturesque headgear worn by any tribe of people anywhere. When the Treasury Department in improving the style of art exhibited on our coinage wished to select a fine-looking Indian as model for the head on the five-cent piece, they turned to a member of one of these Plains tribes.

The dwelling of these Indians was the tipi, or teepee. That this structure should ever be confused with the wigwam is surprising, for the two are very unlike. The tipi is a movable tent, covered with skins, conical in form, with the poles of the framework jutting out of the top. It forms a very tidy, serviceable, and picturesque habitation and, furthermore, one that is quite distinctive. Tribes like the Yakuts of Siberia have tents that are hemispherical, not conical, and covered with felt, not skin. Tents of the Lapps and Samoyeds likewise differ from the tipis for the tipi cover is cut, or "tailored," in a pattern that is perfectly distinctive. I do not know of any habitation in any part of the world that is really comparable to the tipi.

The tipi, exclusive of the furnishings within it, consisted of two parts, a set of poles for the framework and a cover of dressed buffalo hides, the latter carefully tailored and stitched together. This was stretched over the poles and pegged down to the ground when the structure was set up. The poles, preferably of the so-called lodgepole pine, were long, slender, and elegant—long enough to project eight or ten feet above the top of the tent.

In setting up the tipi two poles were put together in the form of a V and lashed at their intersection with the end of a rope, the rest of which was left dangling. A third pole was then fastened to the apex of the V, and the three were raised into the air to form a tripod.

This was the foundation of the tent. Additional poles were carefully laid in place, the woman—for this was women's work—tossing a turn or hitch of the rope over each new pole and binding the whole firmly together. Certain tribes, like the Blackfeet, used four poles, not three, for the foundation of the tipi. In any case, the finished framework was a smooth conical structure of bare poles. The cover was next hoisted into place and stretched around the framework, being pegged down to the ground all around. Where the two edges of the cover met in front, a set of long slender wooden skewers were used to fasten them together. The cover was so shaped that at the top of the tent there was an opening left for the escape of the smoke, and flanking the smoke hole were two flaps known as "ears." Into a pocket at the tip of each ear was inserted a long slender pole, and these poles leaned against the tent, the lower ends extending back of the structure and resting upon the ground. With the help of these two poles the "ears" were moved this way or that, according to the direction of the wind. A tipi without "ears" is an impossible dwelling, for it will not draw properly and will certainly be filled with smoke a large part of the time. The experienced housewife will, if the tipi gets smoky on a gusty day, slip outside, and, with the skill of long practice, shift the direction of the ears a little. When a family shifts its quarters, the tipi is quicky struck, the cover rolled up, and two of the longest poles crossed like a V over the back of a pony, the ends trailing on the ground and constituting a *travois*. The family property, the cover, and the extra poles are loaded on the travois and dragged away. Sometimes the tents of a whole village would be struck at the same instant, and in a few minutes each family would be loaded up, and the procession ready to start.

Not infrequently the earth was excavated a little in the center of the tipi and piled around the edge. Indians lived in such structures during the coldest weather, even in Dakota. Curiously enough, tipis are described as being, on the whole, warm and comfortable. The Indians have a special knack for picking out suitable sites. There is many a spot in corners of the rolling plains country where, in the lee of a hill or tucked away under cover of the cottonwoods which border a creek, there is shelter from the full rigors of winter. In hard weather the great Indian encampments broke up, the families moving hither or thither, wherever they could find a spot sheltered from the wind.

The distribution of this type of dwelling within the historical period was dependent upon the distribution of the buffalo. A whole tribe would sometimes hang on the flanks of a buffalo herd, moving as the herd moved. The horse had the effect of making the Plains

Indians migratory and the consequent effect of enormously increasing the usefulness of the tipi. In more ancient times the Plains Indians undoubtedly ate buffalo meat, when they could get it, and undoubtedly had tipis. But the migratory way of living exclusively in tipis had not developed. We can glean some knowledge of the houses of that ancient period by excavation of old sites and through the fact that some tribes retained the older form of structure until recently. The characteristic habitation prior to the tipi seems to have been a lodge, excavated in the ground, roofed with poles, and heaped over with earth, forming a sort of mound with the dwelling partly subterranean. This type of dwelling seems to have been distributed over a large part or all of western North America. It is, therefore, the next type of habitation to be examined.

THE UNDERGROUND HOUSE OF WESTERN NORTH AMERICA

West of the 100th meridian, which marks the line between moist and arid regions, the habitations seem to be designed to give shelter from winds rather than from rain. There is along the Pacific coast, to be sure, from northern California to southern Alaska, a narrow strip with a reputation for heavy precipitation. Although in parts of the strip, for example in southern Alaska, the precipitation is actually enormous, in a great part of it the rainfall is not really excessive. Portland, Oreg., for example, has about the same annual rainfall as Washington, D. C. The strip offers a violent contrast, however, with the exceedingly arid lands to the eastward. Over the whole western side of the continent, wet and dry, we find habitations which may be classed under the general term "pit dwellings," for they all contain a central excavation. In the three geographic regions into which this western area may be divided, Plains, Plateau, and Pacific Slope, the size, shape, and materials of the house are greatly modified by local conditions.

The original type has been best preserved apparently on the Plateau. The tribes here are very conservative, and their culture is backward in other matters than houses. We may begin, therefore, by looking at the underground house of the Plateau with the presumption that it represents an archaic type. It has spread from the Plateau proper down into certain areas in the central part of California, along with other elements of Plateau culture.

The earliest description of such houses was penned by Sir Francis Drake, who landed on the coast of California north of where San Francisco now stands, in 1579. This place, now called Drake's Bay, he named New Albion. He describes the houses of the natives at this point as follows: "Their houses are digged around about with earth, and have from the uttermost brimmes of the circle clifts of

wood set upon them, joyning close together at the toppe like a spire steeple. * * * Their bed is the ground * * * and lying about the house, they have the fire in the middest." [1]

The method of building these houses, as described by modern observers, may be outlined as follows. The earth is dug up and removed from a circular depression until a deep pit is formed. The sides of this pit are lined with timbers or slabs. Posts or supports are set up in the center, and beams extend from these center supports

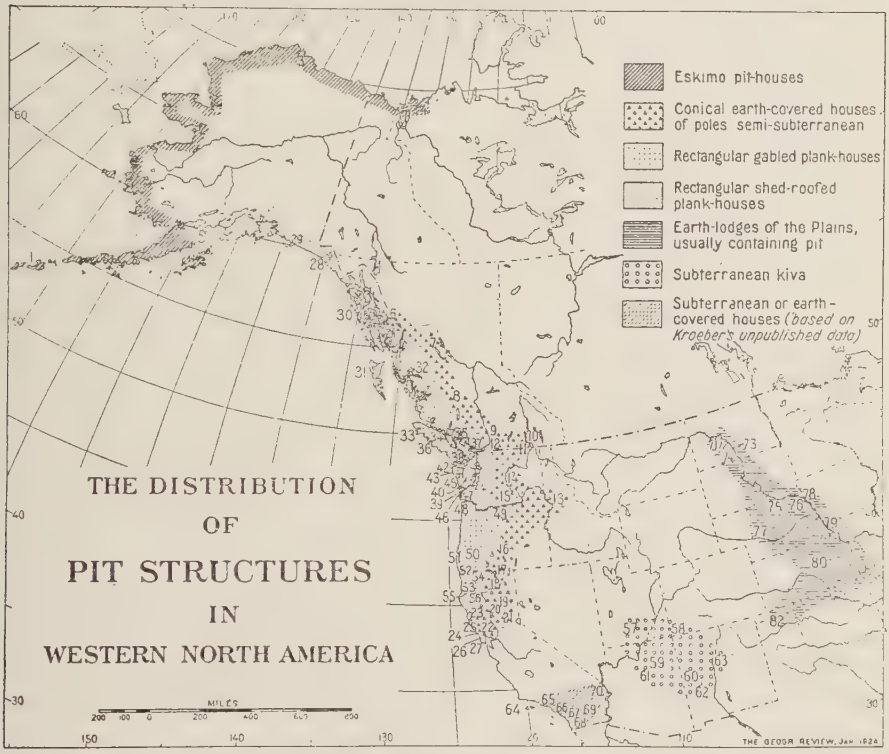

FIG. 1.—Map showing the distribution of pit structures in western North America. (From T. T. Waterman and collaborators: Native Houses of Western North America, Indian Notes and Monographs.) Museum of the American Indian, Heye Foundation, 1921

to the side walls, forming the framework of the roof. This roof is later covered in with poles, or split logs, thatched with grass, and heaped over with earth. The entrance to the dwelling is through a hole at the top, which serves also as a chimney for the escape of smoke. Descent is effected by a ladder consisting of a half log, split

[1] The Course Which Sir Francis Drake Held from the Haven of Guatuleo in the South Sea on the Backe Side of Nueva Espanna, to the Northwest of California, etc. Reprinted in Richard Hakluyt: The Principal Navigations, Voyages, Traffiques, and Discoveries of the English Nation (12 vols., Glasgow and New York, 1903–1905), Vol. 9, pp. 319–326; reference on p. 321.

lengthwise and having notches cut in it for placing the toes. Sometimes these houses are very large, giving accommodation to a number of families. The whole structure is substantial and solid.

The detailed construction of this house differs from tribe to tribe. It may be said, however, that this type of dwelling, including the entrance through the smoke hole, is found over a very large area in the interior of British Columbia, Washington, Oregon, and California—an area characterized by two things, aridity and the relatively low or simple culture of the tribes. The most characteristic forms are found perhaps among the Shushwap and Lillooet. The distribution of tribes which have, or have recently had, such houses is shown on Figure 1.

MODIFIED FORMS OF THE PIT DWELLING: THE EARTH LODGE OF THE PLAINS

In near-by areas, where different conditions were encountered, the lodge became somewhat modified in form. For example, among most tribes on the Plains the pit became so shallow that the structures can hardly be described as pit dwellings. The general form was similar, but the space where the family lived was scarcely below the level of the ground, the excavation going down in some cases only one foot. In many localities, however, as in the houses reported from the Oto, Osage, Omaha, and Ponka, the pit was dug four or five feet deep. In some cases, as among the Pawnee and Hidatsa, the houses were entered through the smoke hole. With the Hidatsa this happened only on "rare or special" (ceremonial?) occasions. There can be little doubt but that these earth lodges, widely distributed among the Plains tribes, were the same thing as the pit dwellings of the Plateau. The structures are always covered over with earth, so much so that they look almost like natural mounds, whence the common term "earth lodge." The sloping roofs of these dwellings, covered with turf, offered an ideal vantage point for observation. On the inside the lodges were roomy and quite comfortable and reported to be warm even in the most severe weather. The family life grouped itself around the fireplace in the center. After the introduction of horses, these animals were often stabled in one corner of the dwelling; this was the case, however, only with highly valued animals. The best and most commodious dwellings of this type were found, perhaps, among the Mandans who at one time had very large villages on the upper Missouri. The Arikara and Pawnee also furnish good examples. (See pl. 5, fig. 1.)

It is interesting to note that some ancient houses in this region are described as entirely underground, being entered from above by means of a ladder. Thus, as we go back in the history of the region, the resemblance of the dwellings described to the characteristic pit

dwelling of the Plateau becomes more marked. Such old structures have recently been reported from eastern Nebraska, where they were excavated by Sterns,[2] and we have historical evidence that they formerly existed, for they were reported by an observer among the Pawnee in 1825, who saw them actually occupied.[3]

UNDERGROUND STRUCTURES IN THE SOUTHWEST

In the southwestern United States we enter an area quite different geographically from the one we have been discussing. It has, of course, an even higher degree of aridity, while the surface is excessively broken up. Human life would seem to be confronted by much more serious difficulties than elsewhere. Yet certain tribes here reached a much higher level of culture than the other tribes of North America. The native habitations here at the present time have little about them to suggest pit dwellings. On the contrary, they are quite lofty and pretentious structures, sometimes four or five stories high. It is certain, however, that there were formerly pit dwellings in this area; and it is possible to trace the evolution of the modern pueblos from underground structures.

Several pieces of incontestable evidence point in this direction. In the first place, in the midst of the modern composite structures, which have square rooms and several stories, there are found certain ceremonial chambers, circular and subterranean, entered by a ladder through the roof. These are known by the native term *kiva* or the Spanish term *estufa*. The reason for these underground chambers has always been a problem, though Cushing long ago suggested that the people may formerly have lived in underground houses but under later conditions preserved these chambers for religious ceremonies.[4]

This idea seems the more plausible when we consider the whole history of architecture in the region. It is a somewhat complicated matter, but certain stages may nevertheless be recognized. Beginning with the modern villages and going back, we can recognize an architectural tendency toward greater compactness in the more ancient structures. At the time of the coming of the Spaniards the villages occupied better defensive positions than they do at present. When afraid of enemy attack the people moved their villages to the tops of the mesas, or flat-topped mountains. Some of these early structures which chanced not to occupy good de-

[2] F. H. Sterns: Ancient Lodge Sites on the Missouri in Nebraska, Amer. Anthropologist, Vol. 16 (N. S.), 1914, pp. 135–137.

[3] W. E. Doyle: Indian Forts and Dwellings, Ann, Rept., Smithsonian Inst. for 1876, pp. 460–465; reference on p. 462.

[4] F. H. Cushing: A Study of Pueblo Pottery as Illustrative of Zuñi Culture-Growth, Ann. Rept. Bur. of Amer. Ethnology for 1882–83, pp. 473–521; reference on p. 476.

fensive sites were very carefully planned for military strength. The finest example of this is the pre-Columbian structure known as Pueblo Bonito, an ancient site at the foot of a cliff in Chaco Canyon. This site has been intermittently under process of excavation for thirty years.[5] No modern village is so compact and well planned as this ruin. At a still earlier stage the village Indians often moved their towns bodily into a cave in the cliffs. It is unquestionably true that cliff dwellings represent a bygone stage in the history of these Southwestern or "Pueblo" tribes. The cliff ruins, which have been well known for fifty years and often illustrated, contain the same square rooms and the same circular, subterranean ceremonial rooms, and, it might be added, the same general types of pottery, basketry, stone implements, and ceremonial objects as the modern pueblos.

Recent excavators have brought to light a still earlier stage of culture preceding the cliff dwellers—that of the so-called "basket makers." Apparently before the southwestern tribes built the great composite clusters of square or rectangular structures which we call pueblos or cliff dwellings, they had small scattered structures, each family in a separate house. The houses, only scanty ruins of which have so far been brought to light, were apparently circular, subterranean, and entered through the roof.[6] These round houses represent the very beginning of masonry in this region, and the people were basket makers rather than potters.

The process by which isolated, circular, underground houses became square or rectangular chambers in aboveground structures is a little puzzling. According to Cushing it was not a replacement of one type of dwelling by a different type but a gradual modification. As the people became more successful farmers, they moved, Cushing thinks, into the cliffs for security for themselves and for the little stores of corn about which they seem to have been even more concerned. The structures came to be built above ground because they could not be excavated in the rock of the cave floors. They became rectangular as the mere result of being crowded together in the limited confines of a cavern. For the same reason they came to be piled one upon another. Meanwhile the ceremonial chambers were made underground at any hazard, either by digging in or by building around and heaping over. Some kivas both

[5] The National Geographic Society has exploration under way at Pueblo Bonito under Neil M. Judd of the Smithsonian Institution. See Natl. Geogr. Mag., vol. 39, 1921, pp. 637–643; vol. 41, 1922, pp. 321–331; vol. 44, 1923, pp. 99–108, and the Annual Reports of the Smithsonian Institution.

[6] M. R. F. and H. S. Colton: The Little-known Small House Ruins in the Coconino Forest, Memoirs Amer. Anthropol. Assn., vol. 5, 1918, pp. 101–126; reference on p. 126; Walter Hough: Exploration of a Pit House Village at Luna, N. Mex., Proc. U. S. Natl. Museum, vol. 55, 1919, pp. 409–431; reference on p. 415; N. M. Judd; Archeological Investigations at Pueblo Bonito, New Mexico, Smithsonian Misc. Coll., vol. 74, No. 5, Washington, D. C., 1923, pp. 134–143; reference on p. 141.

ancient and modern are themselves rectangular, but the others seem to be much more characteristic.[7] Apparently we have in the exceedingly picturesque and interesting structures of the Southwestern Indians a progressive transformation of a very ancient, simple, and wide-spread type of dwelling which we have already traced in other areas.

PLANK HOUSES OF THE TRIBES OF THE PACIFIC SLOPE

On the western edge of the continent along the Pacific Ocean, in the narrow rainy belt already mentioned, the Indians make houses that are outwardly as different from any of those we have been discussing as could well be imagined. The forest trees grow to a tremendous size, from 8 to 12 feet in diameter. The wood is soft, and the logs split easily. The natives work the lumber up in various forms with the help of such primitive tools as stone adzes, mauls, and wedges of yew or antler, and the houses in this entire region are made of plank.

The ordinary notion of Indian dwellings has to be quickly modified when we discuss the plank houses. In northern California, houses are intricate and rather ingenious structures put together with a considerable knowledge of carpentry, without nails of course. In size they are rather small, the largest measuring 18 by 30 feet. The houses of the Columbia River region are somewhat larger, measuring 25 by 75 feet. Farther north again in the region of Puget Sound their size becomes surprising. H. A. Goldsborough, who went inside a house on the present Suquamish Reservation in 1855 and measured all the principal beams, gives its length as 520 feet.[8] A reputable author, Simon Fraser, reports a house standing on the bank of the river now bearing his name, that was 646 feet long and 60 feet wide, saying particularly that it was all under one roof.[9] At the mouth of this river he saw a "fort" (whatever it may have been) 1,500 feet long and 90 feet wide. Hill-Tout, whose statements are to be relied upon, says he has seen a house more than 1,000 feet in length.[10] I have myself seen houses with roof beams more than 4 feet in diameter; and, in other houses, wall planks more than 5 feet wide. The ruins of these Indian plank houses are distributed from Humboldt Bay in northern California to southeastern

[7] P. E. Goddard: Indians of the Southwest, Amer. Museum of Nat. Hist. Handbook Ser., No. 2, New York, 1913, p. 30.

[8] His measurements are quoted in George Gibbs: Tribes of Western Washington and Northwestern Oregon, Contribs. to North Amer. Ethnology, Vol. I, U. S. Dept. of the Interior, Washington, D. C., 1877, pp. 157–241; reference on p. 215.

[9] Simon Fraser: Journal of a Voyage from the Rocky Mountains to the Pacific Coast, 1808 (Les bourgeois de la Compagnie du Nordouest; Récits de voyages, lettres, et rapports inédits relatifs au nord-ouest Canadien, Sér. 1), Quebec, 1889, p. 200.

[10] C. Hill-Tout: British North America, I: The Far West, the Home of the Salish and Déné (Series: The Native Races of the British Empire), London, 1907, p. 51.

Alaska. The most northerly examples I have been able to find in the literature are structures observed by Portlock in Prince William Sound, Alaska, in the year 1789. The main facts about these houses can be summed up by saying that they are always rectangular; are always made of split planks; and always contain in the center a pit or excavation in which the family lived.

When I first looked at the detailed construction of the plank houses in the various parts of this region I received an impression of great confusion. It seemed as if every tribe had a different type of dwelling, and some of them two or three. Boas long ago pointed out that the Haida and Tlingit have one type of house, with three roof beams on each side of the central line, while the Tsimshian and Kwakiutl have another type, with two such beams. To differences in size I have already made reference. The shape of the roof also differs markedly.[11]

When all the facts were plotted on a map, however, a certain amount of system appeared amid this medley. For example, over a tremendous extent of the coast the houses are all of a gabled form, except in a small area about Puget Sound and the mouth of Fraser River where they have a flat or "shed" roof, with a single pitch in place of the gable. In the case of the gabled houses the end of the house is toward the beach; in the case of the flat-roofed house one long side of the structure parallels the beach. In the north and the south there is characteristically one entrance. In the central area there is often a series of openings along the front side with the addition of at least one opening in the rear and still other openings in the ends. The houses of the central area are also of simpler construction than the others. In connection, too, with all gabled houses there is a curious way of giving every house a name. This is not true of the flat-roofed houses. Among the Yurok the names of houses are mostly commonplace. They include such expressions as "at the end of the row," "near the creek," "in the middle," "above the others," "in rear of the village," "set away from the river," "facing the ocean," and other simple descriptive names. I have given elsewhere a list of these Yurok house names.[12] Some of them are a little more ambitious. We find occasionally such names as "big house," "biggest house," "house of feather-plume trees," "where they dance," "where there is sound of dancing." Among the Yurok the thing has taken such a peculiar turn that personal names are supplanted by descriptive expressions based on the names of houses. I have not heard of such a custom in any other part of the world. On the northern

[11] T. T. Waterman and Ruth Greiner: Indian Houses of Puget Sound (Indian Notes and Monographs), Museum of the Amer. Indian, Heye Foundation, New York, 1921.

[12] T. T. Waterman: Yurok Geography, Univ. of California Publs. in Amer. Archaeol. and Ethnol., vol. 16, 1920, p. 208.

Pacific coast, the names of houses are wonderfully high sounding. Often they refer to the totem crests of the owners. Some houses that I have been in myself are "Eagle leg house," "Black-bear house," "Wolf house," and "Killer-whale house." Such names as "Sun house," "Daylight house," "Darkness house," "Moonlight house," "Mountain house," or "Thunder house" indicate the owner's high rank. The names just given are Tlingit from southeastern Alaska. Swanton reports a Haida who had a house so grand that he called it by a name signifying that clouds moving across the sky knocked against it.

The fact that at the northern and southern limits of the region the houses have names certainly suggests a former connection. It is my opinion that the gabled plank houses represent a diffusion up and down the coast. As we go toward the center the size increases; at the ends of the region are similarities of form, though the use of totem poles in the north gives a different atmosphere externally. In the case of all gabled houses the gable end is toward the beach. It is a fair presumption that the flat-roofed houses of the Fraser River region represent a later form, possibly brought in with some less highly cultured Salish tribes which have overrun this region. The gabled form would appear to be the older, and its distribution was probably continuous along the coast at some former period. This appears rather clearly from the map (fig. 1).

The dwelling house in northern California, made of planks split from the redwood tree, was quite a tidy structure. Inside the house a pit was dug, four or five feet deep, in which the inmates lived. Around on a sort of earthen shelf, between the edge of the pit and the walls, was a space for storing things—baskets full of acorns, piles of dried fish and eels, furs, pelts, bows, a thousand varieties of miscellaneous property. A person descended to the bottom of the pit by means of a short ladder of notches in a log. A fire, of course, burned in the center of the pit; and on racks overhead there was usually fish or deer meat in process of preservation. The men were not allowed to sleep within this house. At nightfall all males, young and old, were obliged to go to certain special structures, known as sweat houses. These were underground chambers carefully closed up and almost air-tight. The only time that families were together was during a season in the spring and summer when the Indians scattered, camping along the river and fishing for salmon.

The houses in Alaska were from 40 to 70 feet broad and sometimes 80 or 100 feet long, and I have seen a house pit more than 8 feet deep. Although they did not rival in size the prodigious habitations around Puget Sound, the Alaskan houses were much more elaborate, as might be expected from the fact that these Indians

had a more advanced culture. They are made even more interesting by the presence of numerous totemic carvings. The most conspicuous of these are the gigantic columns known as totem poles. Totemic symbols are carved not only on the totem pole but on the house, inside and out, and on canoes, boxes, dishes, spoons, and a great variety of objects.

That all the rectangular plank houses have pits is a curious thing indeed. It is difficult to see in what way they are advantageous. Furthermore, the rectangular plank structures containing pits are distributed along the margin of an area where genuine pit dwellings exist, i. e., in which the pits are a vital part of the house construction. The simplest explanation would seem to be that the rectangular plank houses represent the transformation of the old conical earth-covered pit dwellings made of poles, in an area where the growth of giant spruces and cedars made the production of wide boards or planks possible and fairly easy. Where the house came to be made of planks the form almost inevitably became rectangular. On the plateau suitable timber for plank houses does not exist. The coast people have never been able, however, to get away from the idea of the central pit.

ESKIMO HOUSES

The Eskimo have two forms of winter habitation, the snow house, built when they are encamped on sea ice, and a form of underground house. The construction of the latter differs widely in the eastern and western parts of the Eskimo area, for in the east the Eskimo is almost entirely without wood. In Greenland, in Labrador, on the shores of Hudson Bay, and westward beyond Boothia Felix the house is made of crude masonry. A pit is dug, and the walls are carried upward with course after course of stone. When flat slabs are obtainable the successive courses project inward, from which it would seem that the Eskimo is trying in a crude way to fashion his roof into an arch or dome. Material for supporting the roof is often hard to find; jawbones of whales are commonly used for the purpose. The house is below the level of the ground; and in summer, when the snows melt, it fills up with water. Then the Eskimo moves out and camps in a tent until winter comes again.

In the western part of Arctic America timber is found in great quantities. Even where trees are scarce large quantities of logs may be obtained as driftwood along the coast. Here the house has been in the past as nearly as possible a replica of the earth lodges of the distant plateau. The modern Eskimo house especially among the Eskimo of Alaska is, to be sure, very different from the earth lodges of the plains, or the subterranean lodges of the plateau.

It is a structure made of plank, but it is entered by a tunnel from one side, and, as described by Nelson, has the interior arrangement which is characteristic of the well-known Eskimo snow house, which is also entered through a tunnel. The modern house, however, is very different from the ancient houses in this region. The houses on the Aleutian Islands are at the present time somewhat Europeanized, having hinged doors, glass windows, and other evidences of contact with Yankees and Russians. The house is covered with earth, however, and so preserves this much of its old character. I was much interested to discover that the houses which were standing in this region something over a century ago, when white explorers first came in, were, as is shown in the drawings reproduced herewith (pl. 9), neither more nor less than pit-dwellings, entered from above through the smoke hole.

The use of underground houses by the Alaskan Eskimo forms a link between America and Asia. In northeastern Asia underground habitations are in constant use, for example, among the Koryak, Chukchi, and Kamchadal. Such pit dwellings have also been reported from Sakhalin Island, from Japan, and from farther afield. It would seem possible that all the underground and semi-underground houses which have been described have been derived at some ancient time from Asia.

The stone houses of the Hudson Bay and Greenland Eskimo, which in all cases are built over pits, may have arisen as a modification of the same form of dwelling, built, however, in a region where there is no timber at all. The snow house is another matter. This seems to be an Eskimo invention, pure and simple.

PUZZLING TYPES OF HOUSES

The Pima of Arizona use a type of dwelling called the kee. It is circular in form, made of wattel, and plastered with clay. It contains no pit. Where they got the plan of this house is very much of a puzzle. The Navajo build a conical type of house which they call the hogan (pl. 10, fig. 1). The framework consists of three poles, which strongly indicates relationship with the tipi of the plains. The center of the house is excavated down into the ground, and the whole is heaped over with a thick covering of earth; both of which features suggest the earth lodge. I admit that I do not know what to make of these structures. The crudest habitation in North America is undoubtedly the wickiup of the Paiute, a brush shelter, shown on Plate 11, Figure 2. Finally there is one tribe of North America, the Seri of Tiburon Island in the Gulf of California, who do not know how to make houses at all. The best they can achieve is a wind break. They live, to be sure, in an all-but-rainless area.

RELATION TO MEXICAN AND CENTRAL AMERICAN ARCHITECTURE

The houses of the Indians of southern Mexico and Central America, to say nothing of the structures of Bolivia and Peru, lead us into another horizon altogether. In these regions the Indian became a real architect. Some of the most imposing stone structures ever raised by the hand of man are to be found in these areas. The pyramids found in Mexico at Papantla, Cholula, and Teotihuacan, recently excavated by the Mexican Government through Dr. Manuel Gamio, actually rival the pyramids of Egypt in size and interest. Great numbers of ruined cities are gradually being brought to light, some of them in the most romantic surroundings. It is worth remembering that the American Indian in certain localities rose by his own unaided efforts to the production of a great architecture, of which the simpler edifices we have been discussing represent the beginnings.

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1. AN OJIBWA WIGWAM IN MINNESOTA. THE HABITATION IS COVERED PARTLY WITH BIRCH BARK, PARTLY WITH BULRUSH MATS

(After D. I. Bushnell, jr., from a photograph in the collection of the Minnesota Historical Society)

2. AN ELONGATED WIGWAM, LARGE ENOUGH TO ACCOMMODATE FIFTY PEOPLE, AS FOUND AMONG THE MENOMINEE, WEST OF THE GREAT LAKES

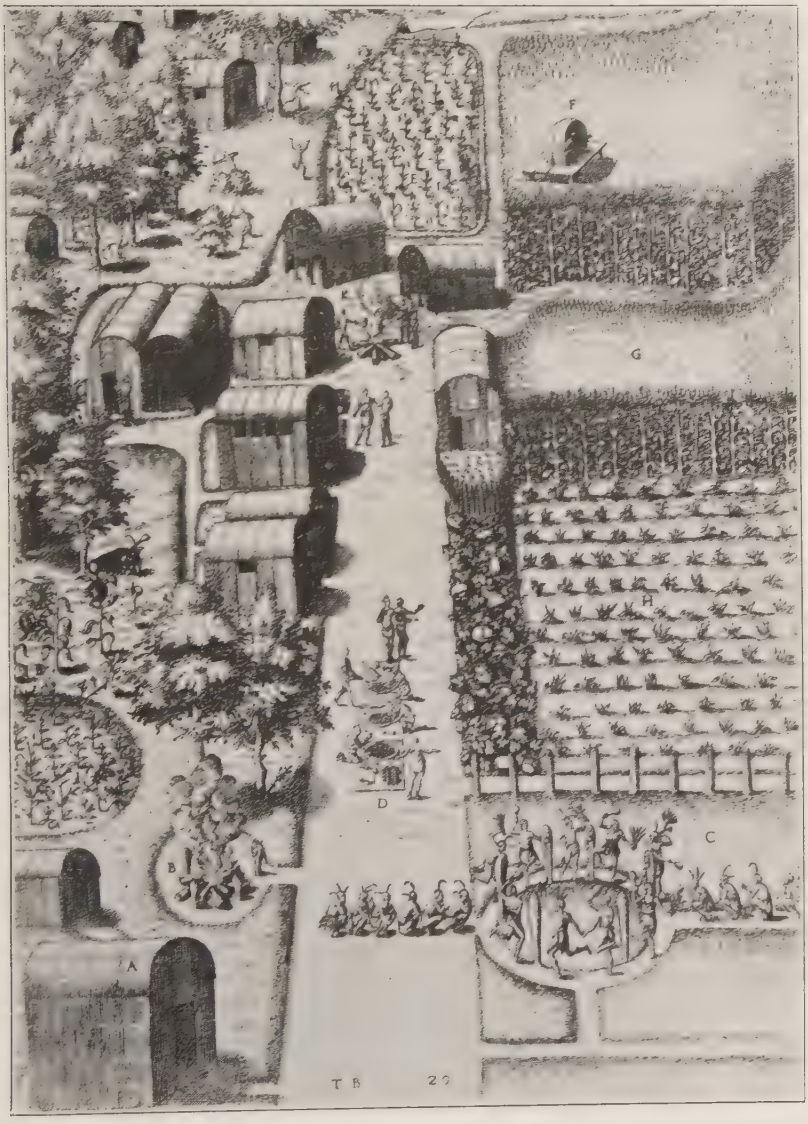
(Photograph from the collections of the Bureau of American Ethnology)

1. A LODGE OF BIRCH BARK BUILT BY PASSAMAQUODDY INDIANS IN THE GROUNDS OF THE SMITHSONIAN INSTITUTION, WASHINGTON. ITS FAITHFUL RESEMBLANCE TO THE OLD STYLE HABITATIONS IS REMARKABLE. IT WAS ERECTED ENTIRELY WITHOUT NAILS

(Photograph by DeLancey Gill, by courtesy of the Bureau of American Ethnology)

2. A CHOCTAW HOUSE IN LOUISIANA, COVERED WITH PALMETTO

(By courtesy of the Bureau of American Ethnology)



A FAMOUS INDIAN TOWN OF EARLY COLONIAL DAYS; THE VILLAGE KNOWN AS SECOTAN, IN WHAT IS NOW NORTH CAROLINA. ALL THE TRIBAL ACTIVITIES ARE IN FULL SWING; TOBACCO IS GROWING IN PLOTS; AND IN THE DISTANCE A MAN IN AN ELEVATED SHELTER IS WATCHING THE CORNFIELDS

(From Thomas Hariot: A brief and true report of the new-found land of Virginia, 1588)

1. GRASS-COVERED LODGE OF THE WICHITA TRIBE

(From a photograph in the collections of the Bureau of American Ethnology)

2. TIPIS, PHOTOGRAPHED AMONG THE SIOUX OF THE PLAINS, ABOUT 1870. THIS UNUSUAL OLD PHOTOGRAPH SHOWS THE LODGES WITH THEIR "EARS," TOGETHER WITH GREAT QUANTITIES OF DRYING BUFFALO MEAT. WOMEN ARE DRESSING BUFFALO HIDES, NUMBERS OF WHICH ARE PEGGED OUT ON THE GROUND

(After D. I. Bushnell, jr., through the courtesy of the Bureau of American Ethnology

1. A VILLAGE OF "EARTH LODGES" ON THE PLAINS, FROM A PHOTOGRAPH TAKEN AMONG THE PAWNEE BY W. H. JACKSON IN 1871. THIS REMARKABLE PRINT SHOWS THE VILLAGERS GATHERED ON THE SIDES OF THEIR LODGES WATCHING SOME CEREMONIAL PERFORMANCE IN THE CENTER OF THE VILLAGE

(After D. I. Bushnell, jr., through the courtesy of the Bureau of American Ethnology)

2. THE INTERIOR OF AN EARTH LODGE, AS PORTRAYED BY THE SWISS PAINTER BODMER, WHO ACCOMPANIED MAXIMILIAN, PRINCE OF WIED, AMONG THE PLAINS INDIANS IN 1833

The furnishings, paddle, weapons, carrying frame, spoon of the mountain-sheep horn, and costumes represent a period when these Indians were little influenced by the whites

1. A VIEW OF WALPI, A TYPICAL VILLAGE, OR PUEBLO, OF THE HOPI INDIANS IN ARIZONA

The structures at the left of the mesa inclose garden patches

2. A CLIFF DWELLING, KNOWN AS CASA BLANCA, OR "WHITE HOUSE." IN ANCIENT TIMES THE SEDENTARY INDIANS TOOK REFUGE IN THE CLIFFS FROM THEIR ENEMIES. IN QUIET PERIODS THE INHABITANTS OF THE SETTLEMENT LIVED ON THE CANYON FLOOR. THE STRUCTURES BUILT IN THE OPEN, LACKING THE PROTECTION OF THE CAVERN, ARE IN A MORE ADVANCED STAGE OF RUIN

(Photograph from the collections of the Bureau of American Ethnology)

THE IMPOSING WALLS OF PUEBLO BONITO, PHOTOGRAPHED AFTER A SNOWSTORM. THIS STRUCTURE WAS A VERITABLE FORTRESS. NONE OF THE MODERN PUEBLOS ARE SO UNIFIED OR COMPACT

(Photograph from the collections of the Bureau of American Ethnology)

AN UNUSUAL PHOTOGRAPH MADE MANY YEARS AGO SHOWING THE CRUDE PLANK HOUSES OF THE CENTRAL PACIFIC COAST REGION, NEAR THE MOUTH OF FRASER RIVER. THE INDIANS HERE, BELONGING TO THE SALISH STOCK, MADE BLANKETS FROM DOG WOOL. CERTAIN DOGS WERE BRED FOR THIS PURPOSE AND WERE SHEARED LIKE SHEEP, AS DESCRIBED BY THE EXPLORER, VANCOUVER. SUCH DOG-WOOL BLANKETS ARE ACTUALLY BEING WORN BY THE PEOPLE IN THE PHOTOGRAPH. THE AUTHOR KNOWS OF NO OTHER PHOTOGRAPH SHOWING THIS KIND OF DOG, WHICH HAS BECOME ENTIRELY EXTINCT

(Photograph from the collections of the U. S. National Museum)

1. INTERIOR OF THE ALEUTIAN EARTH LODGE IN FIGURE 2

2. HOUSES OF THE ORIGINAL ALEUTIAN ISLANDERS. THE SIMILARITY TO THE EARTH LODGES OF THE PLATEAU AND THE PLAINS IS REMARKABLE

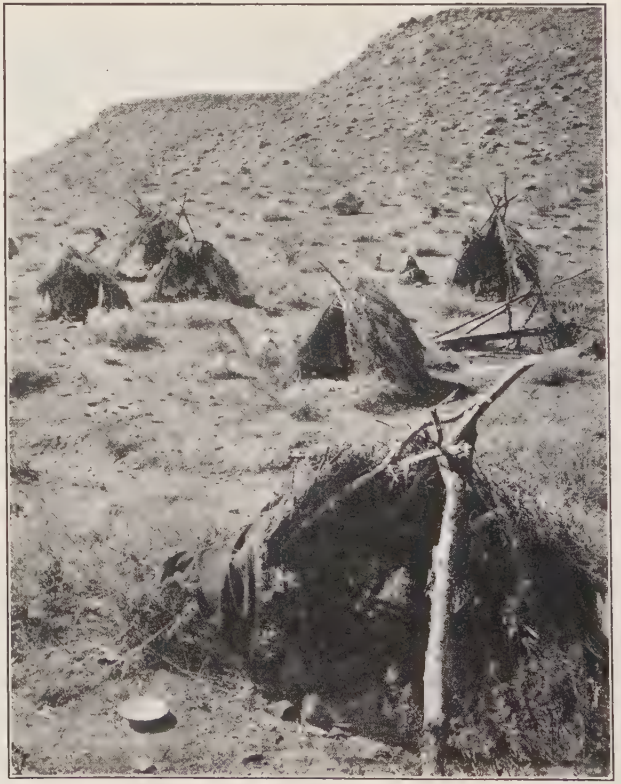
(Reproduced from James Cook: A Voyage to the Pacific Ocean, London, 1784)

1. A NAVAJO "HOGAN," A CONICAL EARTH-COVERED DWELLING
(From a photograph by George Wharton James in the collections of the Bureau of American Ethnology)

2. A WINDBREAK ERECTED BY THE PAPAGO INDIANS OF THE ARIZONA DESERT. THE SERI, LIVING ON THE GULF OF CALIFORNIA SOUTH OF THE PAPAGO, ARE SAID TO HAVE NO ROOFED STRUCTURES; THE COUNTRY IS PRACTICALLY RAINLESS, AND THEY SEEK SHELTER ONLY FROM THE WIND
(Photograph from the collections of the Bureau of American Ethnology)

1. An Indian House on the Northwest Coast

The trees in this area are very large and easily split into planks. This habitation was erected without nails, saws, or any steel tools. The carvings on the splendid totem pole represent (above) three "watchers," and in order down the column raven, grizzy bear, beaver, and grizzly bear again. On occasions of ceremony visitors enter through the pole. (From a photograph, made some years ago at the Indian village of Masset, Queen Charlotte Islands, British Columbia in the collections of the U. S. National Museum)



2. The Simple Life. A "Village" of Paiute Wickiups on the Plateau of Nevada

These structures may safely be regarded as near the bottom in the evolution of houses

THE NATURE OF LANGUAGE[1]

By R. L. Jones

Research Laboratories of the American Telephone and Telegraph Company, and the Western Electric Company, Incorporated

Primitive man, when he wished to communicate, probably expressed himself by grimaces, vocal sounds, and gestures. Although each of these three agencies is still somewhat employed, the combination of voice and ear has been subconsciously evolved and has survived as economical, most flexible in its capacity for variation, and superior in perceptibility.

According to modern philologists, early utterances were song-like and poetic accompaniments of excited or pleasurable emotion, rich in sound and rhythm but without very definite meaning. The motives for utterance gradually changed, the process of associating sense with sound began, and speech and song came to be differentiated.

Primitive languages, in general, consisted mostly of long words with many difficult sounds. Certain exclamatory sounds came readily to designate personal feelings. Echo words, mimicing nature, came to designate natural sounds or the manner or source of their production. Names of persons and objects were an early development. Most words, however, have had a more obscure and complex history. Evolution has tended to shorten word forms and to drop sounds hard to pronounce or to hear.

As man's powers of analysis have developed language has become more flexible and capable of greater range of expression. The grammar of language in general has become simpler and more systematic.

Men in different parts of the earth have evolved differentiated languages, any one of which is now based hardly at all upon natural suggestiveness but rather upon traditional understandings gradually accumulated. Each language has its own system of elementary

[1] Presented before the following sections of the American Institute of Electrical Engineers: Milwaukee Section, Jan. 11, 1923; Cleveland Section, Jan. 23, 1923; Washington Section, Feb. 13, 1923. Reprinted by permission from Journal of the American Institute of Electrical Engineers, April, 1924.

speech sounds. Since only a limited range and variety of sounds can be spoken, it is natural that there should be many similarities between the speech sounds of different languages. The elementary sounds of a given tongue are combined into syllables and words, and these in turn joined together into phrases to convey ideas, all according to the mutual conventions of the people who use the language.

The voice alone enabled man to communicate under circumstances where his gestures could not be seen and at distances beyond where his facial expression could be made out. In our own times the invention and development of the telephone has marked a new step in the evolution of human society, extending the vocal range of man to extraordinary degrees. Voices are hourly carried with instant speed from one end of the land to the other and it is now possible for a speaker to address at one time a million persons gathered about him or scattered at distant points. Speech is the load which the telephone system transports, and the ear is the consumer of the product. Alexander Graham Bell, inventor of the telephone, as student and professor of vocal physiology gained a deep insight into the mechanism of operation of the voice and ear before his greatest invention was made. Throughout his life he devoted himself to the alleviation of the infirmities of the deaf and the dumb. Interest in the problems of speech and hearing comes naturally, therefore, to the telephone organizations which bear his name by sentiment as well as by the needs of their practice.

This paper refers briefly to the mechanism of speech and hearing and then describes some of the physical data of oral communication which have been obtained by investigations carried on during the past few years. A selected bibliography of published papers is attached. Much of the material brought together and summarized here has appeared in scattered form in the articles referred to.

The organs of speech are the lungs, which by their bellows-like action function as a motor element to supply streams of air which pass in and out through the vocal passages. The vocal cords, the tongue and lips, and the cavities of the mouth, nose, and throat, impress on the air flow variations which are heard as sounds. The vocal cords are a pair of muscular ledges on opposite sides of the larynx which can be stretched and brought together, forming between them a slit of adjustable width through which the breath passes. The opening between the vocal cords is called the glottis. The flow of the breath is modulated to form the sounds of speech by the vibration of the vocal cords and by the resonant reenforcement of the vocal cavities.

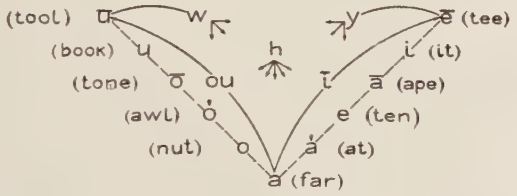
Speech is composed of letter sounds usually divided into vowels and consonants, and those ordinarily used in the English language are tabulated in Figure 1. So far as possible the sounds are ex-

pressed by the letters most commonly used to designate them. In the case of some of the vowels arbitrary markings are employed to distinguish sounds which are different but which are represented by the same letter. The examples given in parentheses will help to interpret the sounds, and it is believed that for most readers the classification will be apprehended more readily with the symbols used than with a system employing entirely different symbols for each sound some of which would necessarily be new and strange.

Fig. 1

CLASSIFICATION OF THE SPEECH SOUNDS

1. Vowels



2. Combinational and Transitional Vowels

w-y-ou-ī-h

3 Seml Vowels

l-r

4. Stop Consonants

Voiced	Unvoiced	Nasalized	Formation of Stop
b	p	m	Lip against Lip
d	t	n	tongue against teeth
j	ch	–	tongue against hard palate
g	K	ng	tongue against soft palate

5. Fricative Consonants

Voiced	Unvoiced	Formation of Air Outlet
V	f	Lip to teeth
Z	S	teeth to teeth
th (then)	th (thin)	tongue to teeth
Zh (azure)	Sh	tongue to hard palate

16526

Readers familiar with phonetics will easily be able to express these sounds in the international phonetic alphabet or in other systems of phonetic symbols.

The classified letter sounds are thirty-six in number. The vowels and consonants may be classified phonetically into (*a*) pure vowels, (*b*) transitional vowels, (*c*) semivowels, (*d*) stop consonants, and (*e*) fricative consonants. Referring to Figure 1, the triangular diagram at the top of the table represents the first two classes. When a vowel is spoken the vocal cords vibrate in a complicated manner,

the characteristics of which are largely determined by the individuality of the speaker. In general, the fundamental or lowest tone of the vibration is rather low in pitch and somewhat lower for men than for women. The mouth and throat cavities, modified by the shape and position of the tongue and lips, act as resonators to reenforce and amplify the relative strength of various harmonics. In this way the shape and position of the mouth and tongue determine largely the particular vowel spoken. The vowel "u" at the upper left of the triangle is formed by rounding the lips, drawing back the tip of the tongue, and raising it at the back in such a way that the throat is almost closed off and the mouth is formed into a single large resonant cavity. Overtones of the cord vibration in the vicinity of about 300 cycles are strongly reenforced. As we come down the left-hand side of the triangle, pronouncing the sounds indicated, the lip opening widens and the jaw is lowered. The tongue is still raised at the back, and we have single resonance until the bottom point of the triangle is reached. In pronouncing the sounds "a" and "á" the lips are wide open. With the former the jaw is dropped, the tongue is only slightly raised at the back, and the most prominent reenforcement is in the neighborhood of 1,000 cycles. With the latter the tongue lies flat in the mouth, and the mouth and throat form connected cavities of nearly equal size. There is double resonance, the two reenforced tones lying in the region from about 800 to 1,200 cycles. As the vowels on the right hand side of the triangle are pronounced starting upward from "a," the separation of the lips becomes smaller, the tongue is raised in the center, and then further forward. These vowels are all characterized by double resonance. With the sound "ē" the lips are drawn to form a wide slit, the tongue is raised in front until its ridge is closely opposite the roof of the front of the mouth. The tongue is drawn forward so that the back of the mouth and the throat form a large resonant chamber. The small tubular space over the tongue at the front leads from the larger space to the exit at the lips. The two frequency regions, which are characteristic of the sound "e," are in the vicinities of 300 and 2,500 cycles.

The transition vowels or diphthongs are those formed by passing from one vowel to another. For example the sound "ī" is pronounced by forming the mouth as if to say "a" and then rapidly passing to the sound "ē." Similarly, the sound designated by the letter "w" is made by forming the mouth as if to say "ū" and then passing suddenly to any of the other pure vowels.

Ordinarily when pronouncing a vowel the glottis opens gently at the beginning of the sound, and the controlled passage of breath produces the sound. If the vocal cords are separated initially in such a way that the glottis is open and the sound is begun by a rather

forcible expulsion of breath, the letter "h" is prefixed to the vowel. "L" and "r" partake of some of the characteristics of vowel sounds and are usually classified as semivowels.

The stop consonants are those accompanied by the formation of a stop in some part of the mouth. For example, "b," "p," and "m" are all characterized by a stop formed with the two lips. The con-

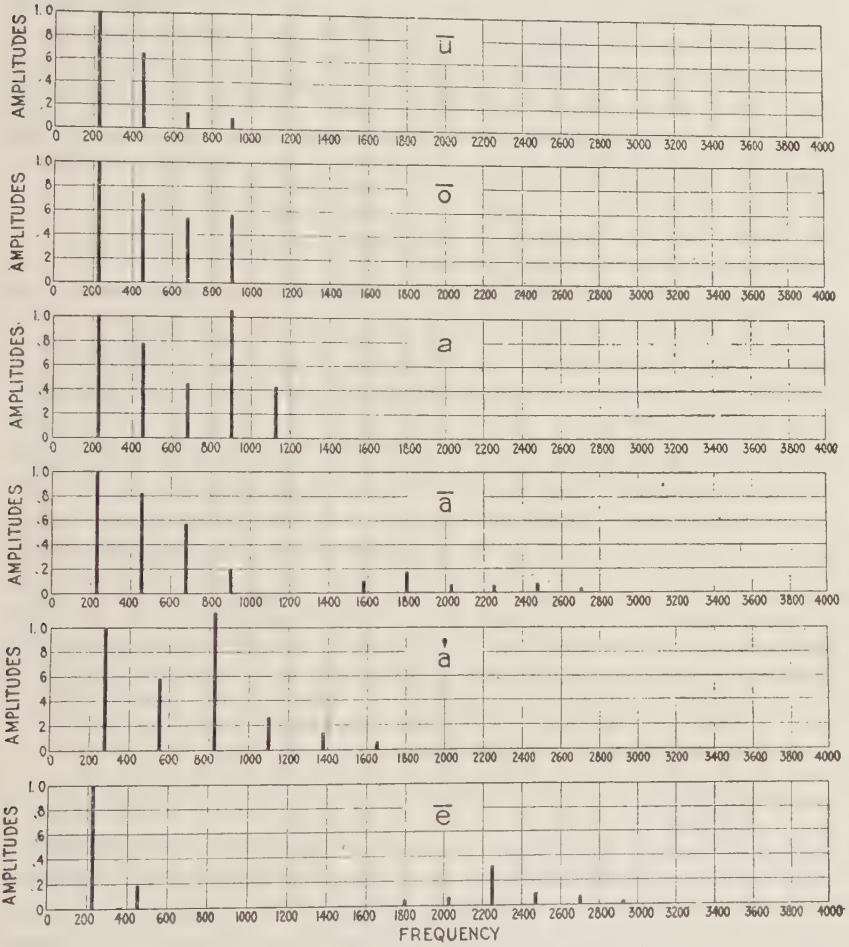


FIG. 2

sonant sound "p" is simply produced by pressing the lips together and then speaking a sound which is begun by having the breath part the lips somewhat forcibly. If the vocal cords are vibrated at the same time, the sound "b" is produced. This accompanying vibration of the cords is the characteristic difference between "b" and "p." For the sound "m" the stop is the same and the cords vibrate.

The "m" sound is nasal. The lips are pressed together and the breath is released through the nose. The stop at the lips is broken when the sound is terminated or when a succeeding vowel begins. The method of producing the other stop consonants can readily be followed from the table.

The fricative consonants are characterized by the rushing sound of the breath through a characteristic air outlet. We have voiced and unvoiced consonants among the fricative sounds as well as among the stop consonants. For example, the sound "f" is produced by forcing the breath through the air outlet between the upper teeth and the lower lip. The sound "v" is formed in the same way except with the accompaniment of vocal cord vibrations. The method of producing the other fricative consonants is easily seen by reference to Figure 1.

The speech sounds thus produced in the course of conversation are radiated from the speaker and transmitted through the air by means of pressure waves. These air vibrations are very tiny and exceedingly complicated. In physical analyses of speech it is usually these pressure waves or their duplicates, converted into electrical vibrations, which are studied. Many of the results here described were obtained with a certain type of high-quality electrical reproducing system or circuit as the basis of the experiments. This system consists of a special form of telephone transmitter, a five-stage vacuum-tube amplifier for magnifying the electric speech currents, and, to terminate the circuit, either a group of telephone receivers of special construction or an experimental type of recording apparatus. The design and construction of this experimental system is such that it is probably the most nearly perfect telephonic reproducing apparatus so far built. Its quality is indistinguishable from that of direct air transmission.

In speaking a given letter sound, only the component frequencies of the particular sound (i. e., a sort of "acoustic line spectrum") are being emitted. By impressing a steady sound on the reproducing system mentioned above and by rapidly inserting in succession suitable sharply-resonant filters covering the range of interest, harmonic analyses of the sustained tone may be made. Figure 2 shows the amplitude-frequency characteristics of some of the English vowels obtained in this way. While these results are typical, it is to be noted that they represent the vowel sounds as pronounced by one particular speaker.

But different speech sounds have different components, and moreover the same sound is frequently pronounced at different pitches, since conversational speech has more or less melody to it. In the aggregate speech may be taken to be represented by a band spectrum. Figure 3 represents the "acoustic spectrum" of English

as obtained from a large number of observations with six different speakers.

Speech energy extends from a frequency of 60 cycles to above 6,000, with a maximum at about 200 cycles. The vowel sounds carry most of the energy of speech and their important frequencies lie below 3,000 cycles. The consonants are the characteristic quips and quirks with which the syllables begin and end. They are weak in energy, but very important to good intelligibility. In general, they are rather high in frequency, some of them involving vibrations going up to a frequency of 6,000 cycles or even higher. The speech energy output of the normal voice has been found to be at the rate of about 125 ergs per second.

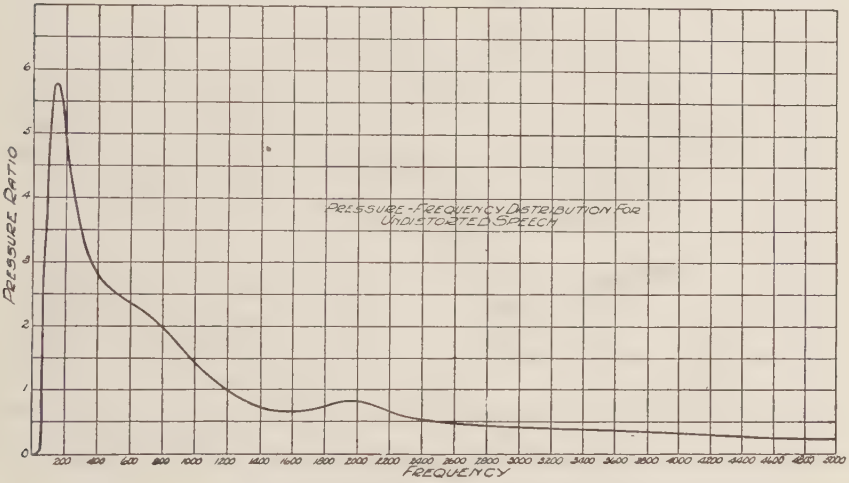


Fig. 3.—"Acoustic Spectrum" of English

In other terms, simple computations show that if we could have a million persons talking steadily and convert the energy of the voice vibrations into heat, they would have to talk for an hour and a half to produce enough heat to make a cup of tea. This merely serves to illustrate that in terms of power or energy human speech is exceedingly weak. Furthermore, most of this energy is carried by the vowel sounds. On the other hand, the consonants, as will be shown, are more important to perception and interpretation by the ear, so that energy per se is not so much the primary requirement of speech reproduction, but rather its distribution, and particularly its distribution among the higher frequencies.

The human hearing mechanism is usually considered to have three parts. The outer ear includes the lobe, the ear canal, and the drum. The middle ear is a small hollow space containing the chain of small bones (malleus, incus, and stapes) which comprise

the mechanical transmission chain for carrying sound vibrations from the ear drum to a small annular membrane, the fenestra ovalis or oval window. The middle ear also contains the muscles which condition the drum and transmission chain so as to accommodate the mechanism to hearing under the variety of actual conditions.

The inner ear is a spiral space in the bony shell called the cochlea. This space is filled with fluid. It is separated into two compartments by the narrow flexible basilar membrane except at the apex of the cochlea where a tiny passage, the helicotrema, connects the two compartments. At the base of the cochlea there is a membraneous diaphragm, commonly called the round window, located on the other side of the basilar membrane from the oval window. Within the spiral casing and terminating on the dividing membrane is the multitude of terminals which connect with the hearing center of the brain through the auditory nerve.

Sound vibrations are transmitted by the stapes through the oval window to the inner ear. At ordinary frequencies vibrations are transmitted through the fluid to a proper distance along the basilar membrane (the appropriate position depending upon the frequency) where they are passed through the membrane and sensed. The excess of vibratory energy transmitted to the second compartment is relieved by the flexibility of the round window. The pitch of a simple tone depends upon the position of maximum response of the basilar membrane—high tones near the base, low tones near the apex of the cochlea. The brain is believed to detect the pitch by its experience in associating tones of different pitches with the stimulation of different nerve groups. When the pitch of the tone is very low, the fluid is moved back and forth around the basilar membrane through the helicotrema. Such impulses follow each other so slowly that the stimulation of the nerve fibers thereby produced is not of the type commonly recognized as a sound sensation. If the pitch of the tone is sufficiently high, the vibratory impedance of the ear mechanism is such that little or no energy is communicated to the inner ear, and in that event also the nerve terminals are unaffected.

The transmission efficiency of the mechanical system linking the ear drum with the basilar membrane is not equal at all frequencies, and its operation varies also with the intensity or loudness of tone. Changes of intensity are probably detected either by change in the amount of agitation of the nerve terminals or by bringing into play wider zones of nerve terminals in the vicinity of the greatest vibration. The marvelous delicacy of the ear mechanism is called to attention when one considers that, in the average case, the basilar membrane by means of which all of these various tones are sensed is only a little over an inch long.

Figure 4 is a plot of auditory sensation for the average human ear. The lower curve shows the sensitiveness of the ear for sounds of different pitches and is called the threshold of hearing. The data were taken by measuring the least sound which could just be heard at each of a number of frequencies. The sensitivity is measured in terms of the minimum audible sound pressure while the frequencies are arranged according to musical intervals (logarithmic scale). The upper curve shows the extreme values of loudness at which the ear begins to experience the sensations of feeling the vibrations. This is the threshold of feeling and may be considered practically as a maximum audibility curve. Sounds much louder than these are painful. The two curves enclose the area of audition. The data have been extrapolated at high and low frequencies to the points of intersection, the extrapolation being guided to a certain extent by other available information. At frequencies in the neighborhood of sixty cycles a high intensity is felt as a sort of flutter. As the frequency is lowered still further to the point where the hearing and feeling lines appear to intersect, it is difficult to distinguish between the two sensations. For frequencies lower than this it is easier to feel than to hear the air vibration. A similar intersection of the two curves occurs at a very high frequency. This appears to give a logical basis for defining the frequency limits of hearing, and as seen from the plot they are about 20 and 20,000 cycles respectively for persons of average hearing. At the lower and upper limits of audition it takes about a hundred million times as much energy to enable one to hear as it does in the range of 1,000 to 5,000 cycles where the ear is most sensitive. At all frequencies the energy required is small, and in the most favorable region the minimum audible tone corresponds to a pressure change per square centimeter of about 0.001 of a dyne. This pressure is roughly equivalent to the weight of a section of a human hair about one-thousandth of an inch long (about one-third as long as its diameter).

In the portion of the audible region most commonly used, it is found that the smallest change in the intensity of a tone which is just discernible, is equal to about one-tenth of its original value. In other words, in general the law connecting loudness discrimination with the energy of the tone is a simple logarithmic one. It has been proposed that change in loudness sensation be measured in units such that a loudness change is equal to ten times the common logarithm of the ratio of the energies.

It has been found that the law of pitch sensibility is approximately logarithmic also. The fractional change in frequency which is just perceptible is equal to about three-thousandths over the greater part of the ordinary musical range. The ear perceives octaves as somewhat similar sounds. With these and other facts of hearing in

R.M.S. Pressure Amplitude (dynes)
10000
1000
100
10
1
.1
.01
.001
.0001
100,000,000 60
1000000 60
10000 40
100 20
1 0
.01 -20
.0001 -40
.000001 -60
.000000 01 -80
Energy Ratio
Loudness Change
Threshold Of Feeling
Region Most Used In Speech
Region Of Lesser Importance In Speech
Threshold Of Hearing
B 16 32 64 128 256 512 1024 2048 4096 8192 16384 32768 Frequency
300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 Pitch
C c c' c² c³ c⁴ c⁵ c⁶ c⁷ Musical Notation

FIG. 4

mind, it has been proposed to measure pitch sensation on a scale such that the pitch of a tone will be given by one hundred times the logarithm to the base two of the pitch number or frequency. These sensation scales of loudness and pitch are given on Figure 4 in addition to the physical scales of energy and frequency. From the observations made on intensity and pitch discrimination, it is possible to show that approximately three hundred thousand different pure tones are separately distinguishable by the average ear. The number of complex sounds which can be sensed is even much greater.

The nonlinearity of operation of the ear gives rise to a number of interesting hearing phenomena. When a simple tone is made very intense the vibratory efficiency of the middle ear and cochlea are no longer constant. This gives rise to harmonics which cause the basilar membrane to vibrate in other zones than that characteristic of the fundamental. If a second intense tone of another pitch is now impressed, its harmonics are also introduced. Under some conditions combination tones appear having frequencies which are the sums or differences of the fundamentals or harmonics. Some of the combination tones may take the form of beats. Such harmonics, combination tones, and beats are purely subjective effects brought in by the departure from linearity of the vibratory mechanism of the internal ear.

The masking of one tone by another is a second effect of interest. An intense low tone is observed to mask or obscure weaker, high tones; but high tones, even though intense, have scarcely any masking effect on lower ones. The explanation offered for this is that the intense low tone, with its subjective harmonics, sets up vibrations in the basilar membrane which extend along the membrane to a considerable distance from the base of the cochlea so that vibrations of higher frequencies which might otherwise obtain in the adjacent region, are interfered with. With the opposite state of affairs, the high-pitched vibrations extend only a short distance from the base, and more remote portions of the membrane are free to sense tones of lower pitch.

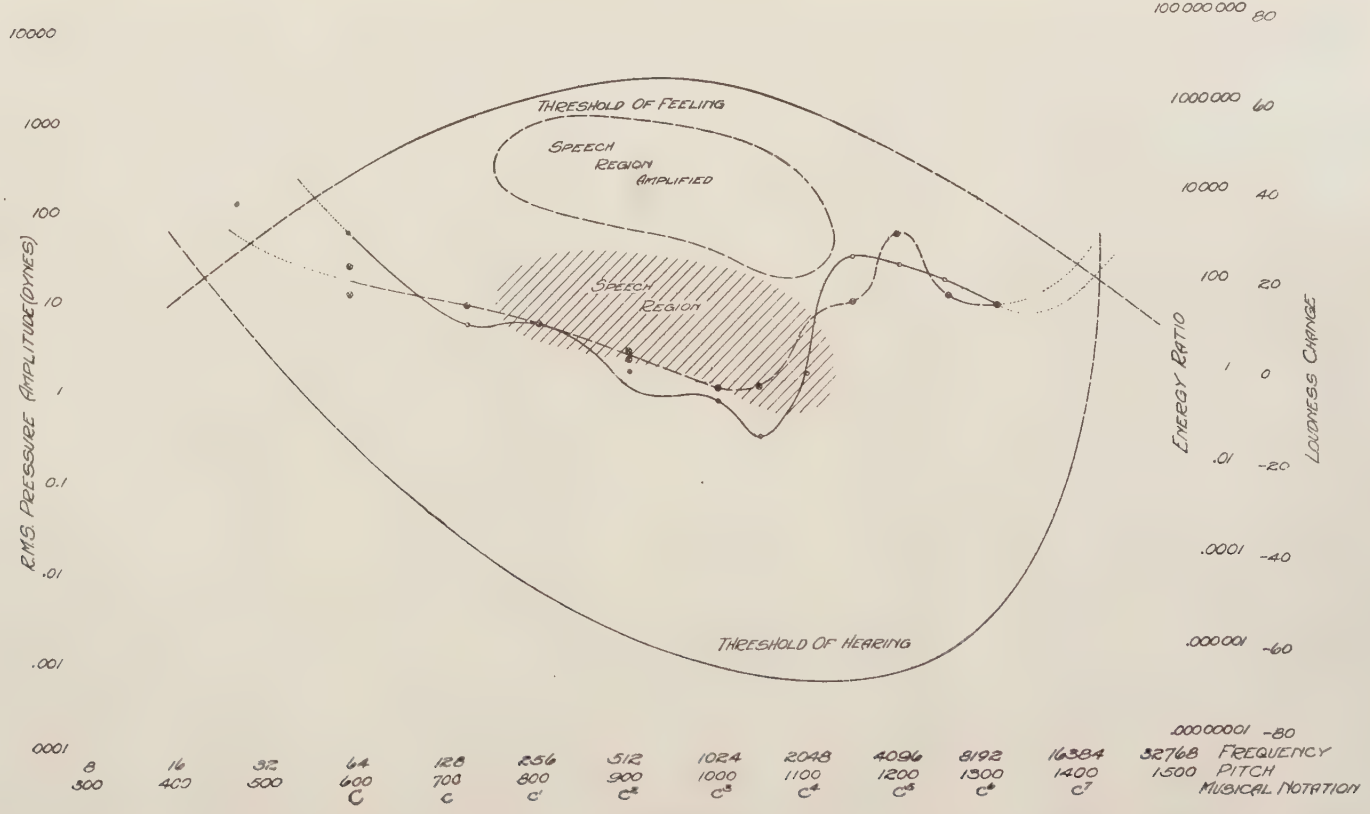
It will readily be apprehended that with complex tones complicated effects may be obtained. When such a tone is made very loud, as by amplification, its tone quality may be greatly altered even though its composition is in no-wise changed. In general its low frequency components will appear more prominent and its higher frequencies diminished.

Referring again to Figure 4, the area of sensation most used in conversation is represented approximately by the shaded area of the figure. The more intense vowel-like sounds account for the upper part of the shaded region, while the weaker consonants account for the most part for the shaded regions of lower intensity

and higher frequency. It is evident that the processes of evolution have worked out in such a way that conversation usually employs the central part of the area of audition. For clear understanding the weaker consonant sounds must not fall below the threshold of hearing nor must the loudest speech sounds rise to such intensity that the threshold of feeling is reached or nonlinear effects introduced.

Defective hearing is lacking more or less in range of sensation (that is either frequency or intensity), quality of sensation in various parts of the sensation area, or in the binaural sense or the ability to locate the direction from which a sound is received. While space will not permit a discussion of abnormal hearing, Figure 5 is presented to illustrate the way in which defective range of sensation may be measured and compared with normal conditions. The area of audition plot is again reproduced together with hearing-threshold curves, or audiograms, for a person whose hearing is subnormal due to catarrhal deafness. The areas between these threshold-of-hearing curves and the threshold of feeling are the diminished areas of sensation for the respective ears. The scales used in plotting the area of audition are such that the area of any part of the diagram represents approximately the number of simple tones which can be distinguished in that region. Hence, the proportional part of the whole area in which sensation can still be perceived may be taken as a measure of deafness. It is apparent that the subject retains about 50 per cent of the normal range in this case. He hears and interprets conversation with some difficulty. A suitable deaf set amplifying the speech region to the position indicated by the dashed lines would be of some assistance. Certain of the weaker consonant sounds would frequently be low enough in intensity to drop below the range of his hearing even with this aid, however. If too great amplification were provided, the energy of some of the vowel sounds would give rise to subjective distortion and might even produce painful sensations. It is of interest to note that an unusual degree of nonlinearity is characteristic of some types of defective hearing. It is evident that in prescribing aids for the deaf, great care must be exercised in order that there may be no danger of injury and in order that the best results may be obtained.

For the study of the interpretation of speech it is necessary to be able to adjust at will the loudness of the speech sounds and to introduce determinable amounts of distortion. With acoustic apparatus this is very difficult and consequently for many years meager results were obtained. The recent development of the vacuum tube and the electric-wave filter make it possible to produce the equivalent of the desired changes in the high quality reproducing


10000
1000
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1
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EMS PRESSURE AMPLITUDE (DYNES)
THRESHOLD OF FEELING
SPEECH REGION AMPLIFIED
SPEECH REGION
THRESHOLD OF HEARING
100 000 000
1000000
10000
100
1
.01
.0001
.000001
.00000001
ENERGY RATIO
80
60
40
20
0
-20
-40
-60
-80
LOUDNESS CHANGE
8 16 32 64 128 256 512 1024 2048 4096 8192 16384 32768 FREQUENCY
300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 PITCH
C c c' c² c³ c⁴ c⁵ c⁶ c⁷
MUSICAL NOTATION

FIG. 5

system mentioned above. By means of distortionless controls operating on the amplifier the loudness of the reproduced speech is varied through a very wide range. By inserting electric-wave filters in the circuit the speech waves can be distorted in known ways. For example, a low pass filter suppressing frequencies above 1,000 cycles is connected in circuit and articulation tests made to find the intelligibility carried by frequencies between 0 and 1,000 cycles. For experimental purposes it is practicable to construct such filters in which the suppressed frequencies are diminished to one-millionth or less of the values which would otherwise obtain, while the passed

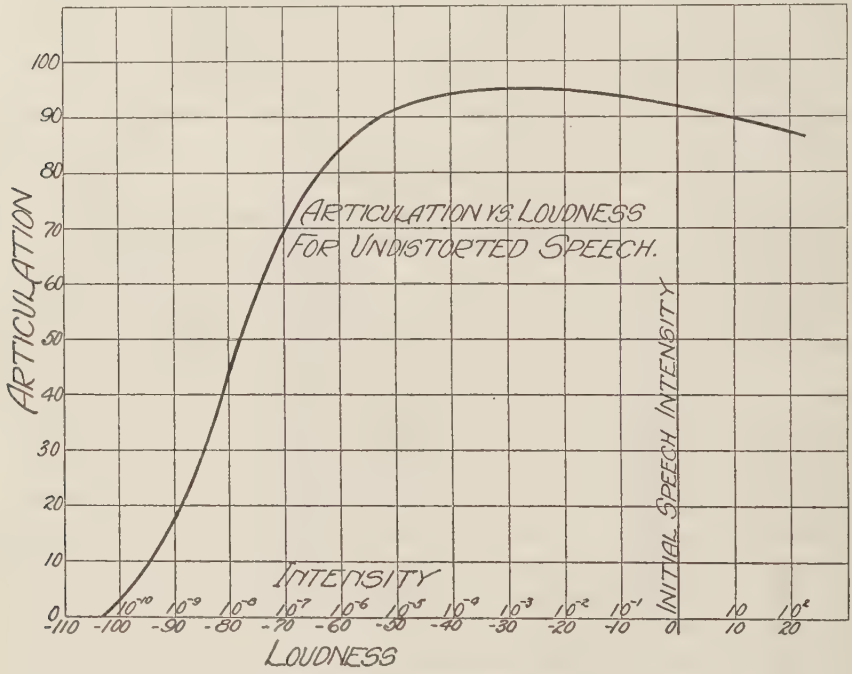

FIG. 6.—Articulation—Loudness characteristic for speech

frequencies are scarcely affected. Similarly high-pass filters can be made which suppress all frequencies up to a certain marginal region and pass those above it. Such filter structures are made by the proper combination of suitable inductance coils and condensers.

Studies of interpretation further require an experimental method for measuring the ability of the ear to understand transmitted speech sounds with different conditions of loudness and distortion The method developed consists in pronouncing detached speech sounds into the transmitting end of the experimental system and in having observers at the receiving end write the sounds which they hear. Comparison of the observed sounds with those called shows

the number and kind of errors made. The per cent of the total sounds spoken which are correctly received is called the articulation of the system. For these tests simple syllables are used constructed in a systematic manner from the 36 fundamental speech sounds and arranged in lists of 50 syllables each. A carefully worked out technique is observed in the testing.

Articulation tests have been made upon the high quality experimental system without distortion, but with controls adjusted to give various intensities of output from the threshold of audibility to values considerably above the level of ordinary conversation. The results obtained are shown in Figure 6. The abscissas of the curve represent loudness and are expressed as the ratios by which the speech energy has been decreased from the initial intensity at exit from the mouth. When the volume is reduced to about one ten-billionth of the initial speech intensity, the articulation becomes zero. This point corresponds to the value at which speech becomes inaudible. At about one-thousandth of the initial speech intensity, the articulation becomes a maximum. With louder speech than this perception is less accurate, probably due to overloading of the ear mechanism and subjective distortion. These results were obtained in a perfectly quiet room. When the observer is submerged in an atmosphere of noise the speech must be louder in order to get the best hearing conditions.

The articulation data have been further analyzed in such a way as to show the errors made at various intensities for each of the fundamental sounds. The results for some typical sounds are shown in Figure 7.

It is observed that in general diphthongs and vowels are more easily heard than consonants, and that of the latter the stop consonants are heard with fewer mistakes than are the fricative ones. If all the sounds are listed in order of average articulation the top quarter will contain no consonants and the lower half no vowels. When speech becomes weak, the errors of the consonants increase greatly, their articulation values falling off at higher intensities than is the case with the vowels.

There are some exceptions to these general statements. At moderate volume the short vowel "e" is near the bottom of the list, but at very weak volume 22 sounds are harder to perceive. "L," "r," and "ng" are all more readily heard than "e" at moderate volume, but when very weak they fall below it. "L," which ranks with the diphthong "i," as one of the easiest sounds at moderate volume, is mistaken about two times out of three when very weak.

The diphthongs "ī," "ou," and the long vowels "ó," "ō," "ā," all have average articulations better than 95 and even when very

weak have values of 84 or better. On the whole the sounds "th," "f," "s," and "v" are hardest to hear correctly, and they account for more than half of all the errors of interpretation. In general, it is observed that the volume at which errors begin to be large is different for different sounds and is usually higher for the consonants than for the vowels. Within the precision of the data,

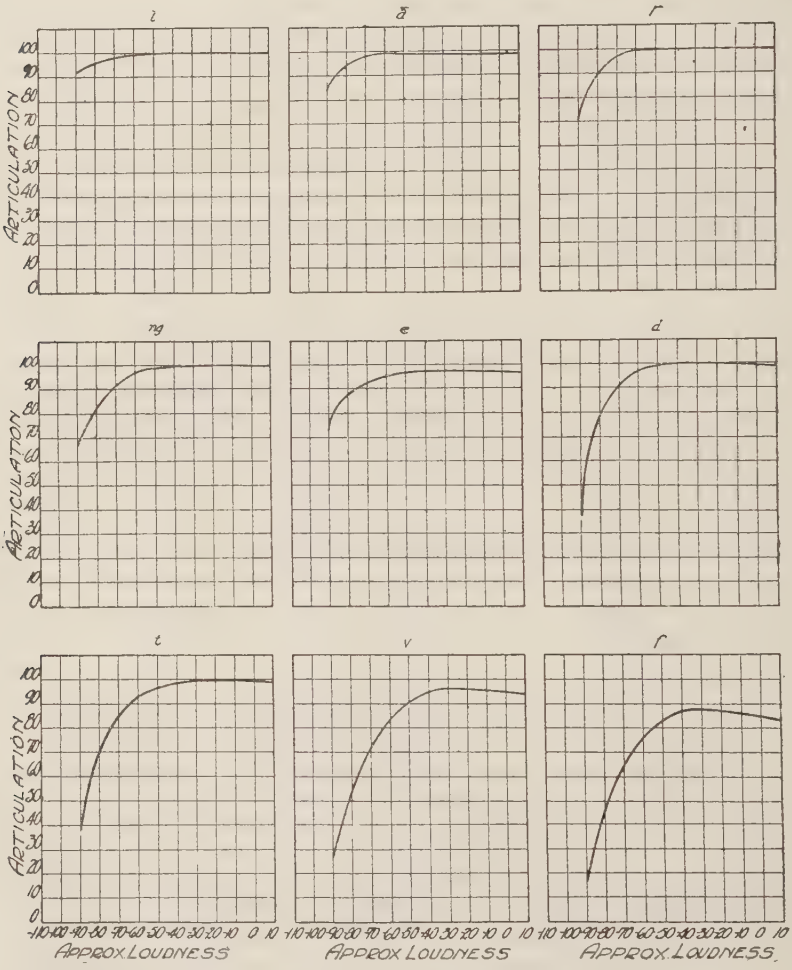

FIG. 7.—Articulation—Loudness curves for some typical speech sounds

the intersections on the axis of abscissas all correspond with the threshold of hearing.

The effect of frequency distortion has been investigated by inserting several systems of electric-wave filters in the high-quality experimental circuit. Articulation results with low-pass and high-pass filters are shown in Figure 8. The ordinates show the per cent of syllables called which were correctly recorded at the re-

ceiving end. The abscissas represent the marginal or cut-off frequency of the filter. Looking at the curve for the low-pass filter, marked "Articulation L," the point (1000,40) indicates that an articulation of 40 per cent is obtained when the system transmits only frequencies up to 1,000 cycles. Looking at the curve for the high-pass filters, marked "Articulation H," the point (1000,86) indicates an articulation of 86 per cent for a system transmitting only frequencies above 1,000 cycles. The dotted curves show the per cent of the total energy in speech transmitted through filters of the two types having cut-off frequencies corresponding to the abscissas. Sixty per cent is lost if all the energy below 500 cycles is eliminated, but only 2 per cent of the articulation. The suppression of the

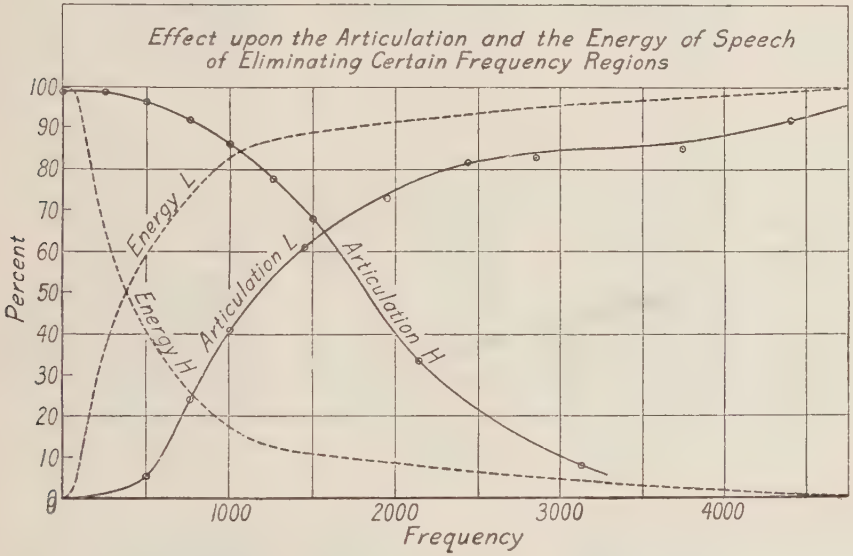

FIG. 8.—Articulation—Distortion characteristics for speech

frequencies above 1,500 cycles reduces the articulation by 35 per cent but only 10 per cent of the energy lies in this region. The suppression of all frequencies below 1,000 cycles has no greater effect than the suppression of the frequencies above 3,000 cycles. This is quite contrary to the popular notion of the characteristics of speech. The mean frequency from the standpoint of articulation is about 1,550 cycles. An articulation of 65 per cent is obtained when either the frequencies below or those above that point are used. The speech quality sounds very different in the two cases, however, in the one being low and dull, and in the other high and shrill.

It should be borne in mind that naturalness of reproduction, as well as articulation, is an important element of understandable and

satisfactory spoken communication. As has been pointed out above, although the fundamental cord tones and harmonics lying below 500 cycles carry most of the speech energy, they contribute little to the articulation. It has been observed that naturalness of reproduction is greatly affected depending upon whether or not these low

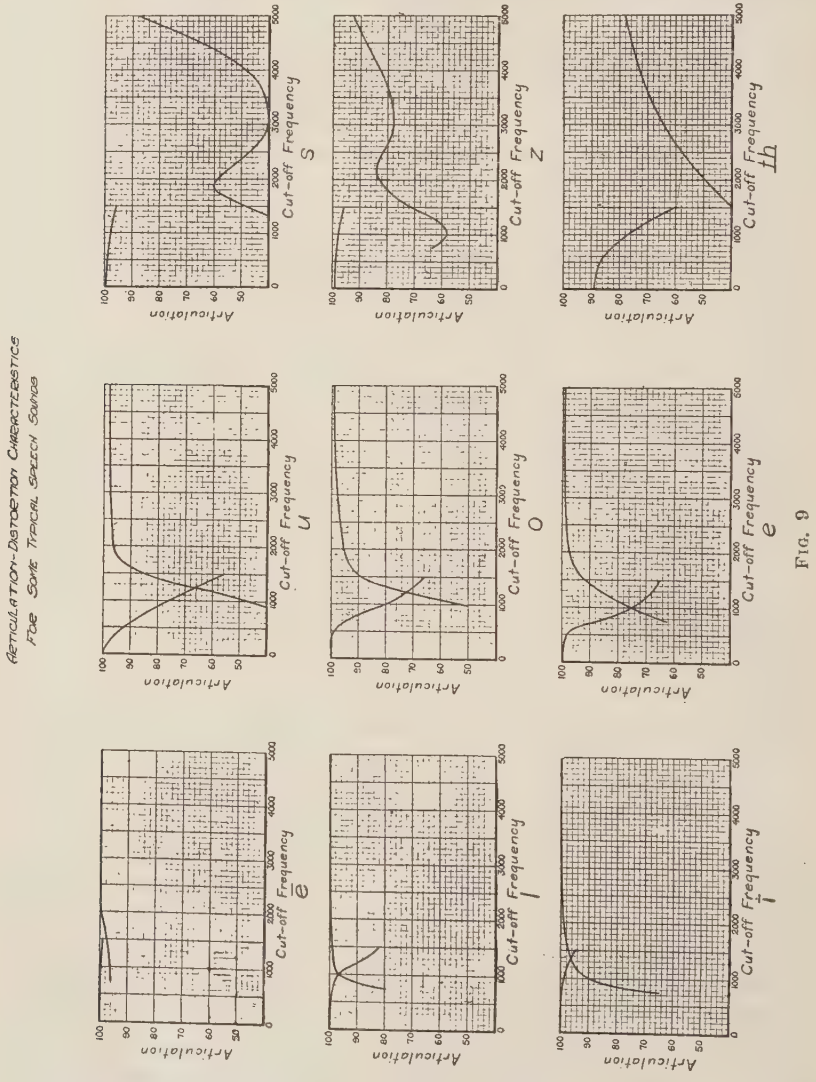

FIG. 9

frequency tones are preserved. While it might be concluded from the articulation data then, that frequencies in the lower part of the speech range are unimportant, a fuller consideration justly attributes an added measure of importance on account of naturalness. The naturalness of speech quality is a characteristic calling for considerable further investigation.

The curves of Figure 9 show the articulation of some typical speech sounds when the frequency regions below or above the given point are suppressed. The ordinate gives the number of times the sound was correctly observed per 100 times called; the abscissa, the frequency of cut-off. In each figure the effect of suppressing the frequencies below the cut-off is shown by the curve at the left, the effect of suppressing those above it by the one at the right. The diphthong "ī," the long vowel "ē," and the semi-vowel "l" are each perceived with an error less than 3 per cent when either half of the frequency range is used. The intersections of the two curves, the cut-off frequency where the articulation is the same with either low-pass or high-pass filters, are at different points in each of the three cases, however.

In the cases of the short vowels "u," "o," and "e," the frequencies below 1,000 cycles are important to good articulation, but those above 2,000 may be suppressed with little effect.

In the cases of the fricatives "s," "z," and "th" quite different effects are observed than with the former two classes. Some of the peculiar results shown have not yet been explained. Even if all frequencies up to 5,000 cycles are correctly transmitted, these sounds are noticeably impaired by the suppression of those above. The lower frequencies up to 1,500 cycles contribute practically nothing to the articulation of "s" and "z." It has been observed, in the case of a system which suppresses all frequencies above 2,500 cycles, that about 82 per cent of the syllables were heard correctly in an articulation test, and that the errors were made up principally of failures in the three sounds "s," "z," and "th."

In conclusion then, we have seen that the ordinary ear is an exquisitely developed organ for sensing minute and rapidly repeated variations in air pressure. It can perceive sound waves ranging in pressure amplitude from less than 0.001 dyne to over 1,000 dynes, and in frequency of vibration from about 20 cycles per second to about 20,000—a range of about 10 octaves. Human speech employs frequencies from a little below 100 cycles per second to about 6,000 cycles—a range of about 6 octaves. The intensities and frequencies used most in conversation are those located in the central part of the area of audition. The energy of speech is carried largely by frequencies below 1,000, but the characteristics, which make it intelligible, largely by frequencies above 1,000. Under quiet conditions good understanding is possible with undistorted speech having an intensity anywhere from one hundred times greater to a million times less than that at exit from the mouth. On the whole, the sounds "th," "f," "s," and "v" are hardest to hear correctly and they account for over half the mistakes made in

interpretation. Failure to perceive them correctly is principally due to their very weak energy although it is also to be noted that they have important components of very high frequency.

These data are of fundamental importance in the art of electrical communication. But they have also a broader interest and utility. The information gleaned by physicists in the study of speech and hearing increases the understanding of phoneticians and physiologists. It will aid public speakers, linguists, and physicians, and help to lighten the burdens of the deaf and dumb. Investigators who engage in the field of human acoustics have many interesting physical problems to solve. Furthermore, study of these senses, dealing as it does with two of the primary tools of the human race, is work of extraordinary appeal holding forth promise of direct service to mankind.

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JOHN MIX STANLEY, 1814–1872

(Photograph made about 1866)

JOHN MIX STANLEY, ARTIST-EXPLORER

By David I. Bushnell, Jr.

[With 7 plates]

During the first half of the last century, when the region westward from the Mississippi was still claimed and occupied by many tribes, for the most part living in their primitive condition, little influenced by contact with the whites, many persons, impelled by different impulses, traversed the country from the river to the mountains. Many, whose purpose was to explore the wilderness, left accounts of their journeys, but countless others failed to leave any records of their travels and experiences. Some, whose talents enabled them to sketch the wild scenes, accompanied the various expeditions; others visited the country for the sole purpose of studying the native tribes in their natural environments, to obtain portraits of individuals and to portray the ways of life of the people with whom they came in contact.

Necessarily the work of the different artists varied greatly in value and importance, but the sketches and paintings made by the subject of these notes, J. M. Stanley, were among the most interesting secured during that period. And as mentioned in the preface of the catalogue of his pictures, which he himself prepared and which was issued by the Smithsonian Institution in December, 1852, the collection included "accurate portraits painted from life of 43 different tribes of Indians, obtained at the cost, hazard, and inconvenience of a 10 years' tour through the southwestern prairies, New Mexico, California, and Oregon." Truly a remarkable collection, and were it in existence at this time would prove of inestimable interest and importance to the ethnologist as well as to the historian. Now before mentioning certain of the pictures in detail let us trace the movements of the artist during his "10 years' tour," during which time he visited the widely separated parts of the western country. The following account of his travels was prepared by his son, Mr. L. C. Stanley, to whom we are also indebted for the photograph of his father which is now reproduced as Plate 1.

"John Mix Stanley was born in Canandaigua, N. Y., 1814, and died in Detroit, Mich., April 10, 1872. At the age of 14 he became an

orphan and was apprenticed to a wagon maker in Naples, N. Y., and spent his boyhood there and in Buffalo.

"In 1834 he removed to Detroit, and in 1835 began to paint portraits and landscapes. In 1838 and 1839 he lived at Chicago and Galena. At this time he made pictures among the Indians near Fort Snelling. During the years 1839–1842 he resided and painted at New York, Troy, Philadelphia, and Baltimore. In 1842, accompanied by Sumner Dickerman, of Troy, he visited the Indian country in Arkansas and New Mexico and made sketches and pictures of the Indians and Indian scenes. In June, 1843, accompanied P. M. Butler, Governor of Arkansas, to a council with the chiefs of many tribes to arrange a treaty of peace between those tribes and the State of Texas, then independent, Governor Butler having been deputed thereto by the Government of the United States, and having requested the company of Mr. Stanley. The council was attended by General Taylor, Captain Bliss, and agents of the Senecas and Delawares. A flagstaff of considerable height had been raised. Mr. Stanley was painting a design on a white flag to be flung from this staff. The design was an Indian's hand clasping a white man's hand. A young Waco chief, 'Shooting Star,' observing this work suggested that the head of a bulldog be painted below the hands to bite whichever hand might prove treacherous.

"In this year Mr. Stanley visited Chief Lewis Ross, brother of Chief John Ross, of the Cherokee Nation, at Bayou Menard. He also visited the Creek Nation on the North Fork of Canadian River where he witnessed the Busk, or Green Corn dance.

"The opportunities afforded by his constant contact with the Indians were improved by almost daily painting and sketching. In attempting to paint the portrait of the Cherokee chiefs Mr. Stanley found a difficulty in their caprice and superstition. They insisted that portraits should first be painted of Jim Shaw, a Delaware, and of Jess Chisholm, a Cherokee, under whose protection Mr. Stanley had been conducted; if these men should consent to sit and should receive no harm from the operation, then the Cherokee chiefs would sit. It was done in this way. They came forward in the order of their rank and were delighted with the idea of being painted, considering it a great honor.

"Mr. Stanley spent part of the year 1845 in New Mexico. By the year 1846 he had painted 83 canvases, and in January of that year he and Mr. Dickerman exhibited them in Cincinnati and Louisville.

"In May, 1846, Mr. Stanley returned to the west and visited Keokuk at his lodge, and made portraits of the wife of Black Hawk and of chiefs of the Sauks. In October, 1846, he visited Santa Fe to paint still more pictures. Here he joined the expedition of Gen. S. H. Kearney, who led the dangerous march overland to San Diego,

Calif. He was placed under the immediate command of Captain Emory, of the Topographical Corps, United States Army. At the mouth of the Gila River they had a battle with some California irregulars. This was during the time when General Flores, the counter revolutionist, held Los Angeles and Commodore Stockton, in opposition, held San Diego. In this march Mr. Stanley was also in the actions at San Pasquale, Calif. In 1847 he proceeded northward through California, and by July reached Oregon. He escaped, most narrowly, the massacre in which Dr. Marcus Whitman, Mrs. Whitman, and 11 others were killed by a few Indian malcontents of the Cayuse Tribe. He was leaving the mission of Walker and Eels at Fort Colville, intending to go to Doctor Whitman's mission. He was stopped by the actions of some Indian children, who indicated danger by making gestures to turn him about in the way.

"In Oregon he made sketches of Mount Hood and of the Columbia River, which river he navigated in canoe for nearly a thousand miles, and later painted two pictures of Mount Hood. He then returned to San Francisco, via Sacramento, and sought to take a certain ship for return to New York around Cape Horn, but was not in time for that ship. It was lost at sea; no lives were saved. Returning on another vessel, he landed at Honolulu, where he remained during most of the year 1848. During his stay he painted the portraits of King Kamehameha III and of his Queen. These portraits hang in the Government Museum at Honolulu, formerly the Royal Palace.

"Returning to this country, Mr. Stanley exhibited his collection of pictures in 1850 at Troy and Albany, and in the following year at New Haven, Hartford, and Washington, D. C. The collection now included the portrait of Chief Hendrick of the Stockbridge Tribe.

"In 1853 Mr. Stanley was appointed to be the artist of the expedition sent by the Government of the United States to explore a 'Route for the Pacific Railroad near the forty-seventh and forty-ninth parallels of latitude from St. Paul to Puget Sound.' Mr. Stanley joined the expedition at Jefferson Barracks, Mo., where it was organized, but the actual start was from St. Paul. Isaac I. Stevens, Governor of Washington Territory, was in command of the expedition. In September, 1853, Mr. Stanley was sent on a special mission to the Piegan and returned with their chiefs, about 30 in number, to a council with Governor Stevens at Fort Benton.

"The Indians were impressed by Mr. Stanley's ability to make pictures of them with his brush. Also the daguerreotype process which he sometimes used was to them a thing inspired because produced by the light of the sun.

"In 1854 Mr. Stanley returned to Washington, where he remained till 1863, when he removed to Buffalo, where he spent a year. In 1864 he began the painting 'Trial of Red Jacket,' a picture containing about 100 figures, and his most important single work. It is now hung in the building of the Buffalo Historical Society, Buffalo, N. Y. His paintings remained on exhibition in the Smithsonian Institution and only five of the collection escaped destruction when the building was damaged by fire, January 24, 1865."

In the catalogue issued in 1852, to which reference has already been made, 151 pictures by Stanley were described. The last item in the catalogue was "152, J. M. Stanley, The Artist. Painted by A. B. Moore, 1851."

The interesting old photograph reproduced in Plate 2, reveals a corner of the picture gallery in the Smithsonian Building as it appeared before the fire. The larger pictures were part of the Stanley collection, but the smaller works on the left may have been some of the Indian portraits by King and others. It will be remembered that many important Indian pictures, in addition to those which formed the Stanley collection, were destroyed by the fire.

The descriptive list of the Stanley pictures, which appeared in the catalogue in 1852, was reprinted in the "Guide to the Smithsonian Institution and National Museum, 1861," consequently it would appear that no additions had been made to the collection during the intervening years. However, Mr. L. C. Stanley is of the belief that the painting hanging near the center of the group, as shown in Plate 2, was a portrait of Gov. I. I. Stevens. It was not the portrait of his father, the artist, number 152 in the list.

The collection had evidently been deposited in the Smithsonian Institution by the artist a short time before he became a member of the expedition, which started in the spring of 1853. As a member of the expedition he made a large number of sketches of the various points of interest, and as a novel experiment he carried a daguerreotype apparatus, probably the first taken up the Missouri. In the report of the expedition is this note: "August 7, 1853. Mr. Stanley, the artist, was busily occupied during our stay at Fort Union with his daguerreotype apparatus, and the Indians were greatly pleased with their daguerreotypes." (Reports of Explorations and Surveys * * * from the Mississippi River to the Pacific Ocean * * * 1853–1855. Vol. XII. Pt. I. 1860. p. 87.)

After the collection had been deposited in the Smithsonian and was open to the public, various attempts were made to have Congress purchase it for the Nation, but without success. The pictures remained the property of the artist, consequently their destruction caused him a great personal loss.

The exact number of pictures in the Stanley collection at the time of the fire has not been ascertained. It is quite difficult to believe no changes or additions had been made between the years 1852 and 1865. However, it is possible the collection was maintained as a unit, exactly as it was when first placed in the gallery of the Institution, and if this were true it is evident 146 of Stanley's paintings were destroyed.

For certain reasons five of the more important canvases had been removed from the "Gallery of Art" to another part of the Smithsonian Building, and, fortunately, the section of the building in which they were placed was not seriously damaged by the diasastrous fire which resulted in the destruction of the balance of the collection. These now form part of the permanent collections of the National Museum.

The five paintings now belonging to the United States National Museum may be considered excellent examples of the artist's work. They are now described in the order in which they were painted. The quotations are taken from the descriptive catalogue, prepared by Stanley:

Plate 3. "International Indian Council. This council was convened by John Ross, at Tal-lequah, in the Cherokee Nation, in the month of June, 1843, and continued in session four weeks. Delegates from seventeen tribes were present, and the whole assemblage numbered some ten thousand Indians."

Tahlequah, where the great gathering took place, was the name applied to the capital of the Cherokee Nation, in the northeastern part of the Indian Territory, in 1839. It is now part of the State of Oklahoma. Tahlequah became an important gathering place for many tribes, and the painting of the assemblage during the early summer of 1843, is one of the most valuable and important Indian pictures in existence.

Plate 4. "Ko-rak-koo-kiss. A Towoccono Warrior. This man distinguished himself among his people by a daring attempt at stealing horses, in the night, from Fort Milan, on the western frontier of Texas. He succeeded in passing the sentries, and had secured some eight or ten horses to a lariat, and was making his way to the gates of the fort, when he was discovered and fired upon. The night being dark, the shots were at random; he was, however, severely wounded by two balls, received two sabre wounds upon his arms, and narrowly escaped with his life. He is about twenty-three years of age, and by this daring feat has won the name and standing of a warrior among his people."

This Tawakoni warrior may have been present at the council of Tahlequah, in 1843; his tribe was one of the seventeen represented at that great gathering.

Plate 5. "An Osage Scalp-Dance. * * * On returning from the scene of strife, they celebrate their victories by a scalp-dance. * * * This picture represents the scalp-dance of the Osages around a woman and her child; and a warrior in the act of striking her with his club, his chief springing forward and arresting the blow with his spear."

A picture possessing great artistic merit. The ornaments and decorations of the Osage are carefully drawn; the many details of the picture are quite remarkable.

Plate 6. "A Buffalo Hunt. On the Southwestern Prairies." The tribe represented in the picture is not mentioned, nor is it now possible to identify the Indian. The scene was typical of the time and place.

Plate 7. "Black Knife. An Apache Chief, reconnoitering the command of General Kearney on his march from Santa Fe to California."

This large canvas, measuring 41 by 50 inches, is shown in the old photograph reproduced in Plate 2. It hangs on the extreme right, third row from the bottom, and knowing its size enables us to form a better idea of the others shown in the same photograph, all of which were destroyed in the fire of January 24, 1865.

The destruction of the collection of 146 paintings caused an irreparable loss, a loss which will be more fully appreciated in the future when the events depicted and the individuals shown will belong to the vague past.

A CORNER IN "THE GALLERY OF ART," SHOWING PART OF THE STANLEY COLLECTION BEFORE THE FIRE OF JANUARY 24, 1865

INDIAN COUNCIL. "CONVENED BY JOHN ROSS, AT TAH-LE-QUAH, IN THE CHEROKEE NATION, IN THE MONTH OF JUNE, 1843." SIZE 28 BY 40 INCHES

(Painted 1843)

"A TOWOCCONO WARRIOR." SIZE 26 BY 30 INCHES

(Painted 1844)

"AN OSAGE SCALP DANCE." SIZE 40 BY 60 INCHES

(Painted 1845)

"A Buffalo Hunt on the Southwestern Prairies"

(Painted 1845)

"BLACK KNIFE, AN APACHE CHIEF." SIZE 41 BY 50 INCHES

(Painted 1846)

HERLUF WINGE

HERLUF WINGE (1857–1923) [1]

By Th. Mortensen

[With 1 plate]

Herluf Winge was born March 19, 1857, the son of C. G. Winge, an official in the Navy Department, and wife, born Mønster. From his earliest boyhood he was, together with his brother Oluf, two years his senior, deeply interested in zoology, especially in mammals and birds, and, above all, in osteology. He made collections of all sorts of bones and trained himself in their identification, and in recognizing and correctly interpreting all sorts of fragments of bones and teeth, a training which became of the greatest importance to the work of his manhood. He entered the University of Copenhagen in 1874 (from the "Borgerdyd" school) and, of course, at once eagerly devoted himself to a thorough study of zoology.

In 1881 he took his master's degree in zoology; from 1883–1885 he was a voluntary aid at the Zoological Museum; in 1885 he was appointed assistant in Department I of the Museum, and in 1892 he was nominated vice inspector of this department, a position in which he remained until his death. He died on November 9, 1923, without any preceding illness. He had, however, aged considerably during his later years, especially after the accident he met with in the winter of 1922, when he fell and broke an arm. But mentally he was in full vigor to his last day and intensely occupied with a great work, in which he intended to sum up the results of all his studies of mammals, studies that had made up the main part of his life's work. It was, perhaps, overexertion with this task which caused his death.

Winge's life formed itself very regularly, without greater events, except for the great affliction he suffered when his brother Oluf died in 1889. He had always looked up to this brother as his ideal, and, to the end, he cherished his memory with the greatest piety, declaring himself to be only a faint reflection of him. Winge was a bachelor and, at any rate in his later years, perhaps slightly eccentric. Whilst in his younger years he enjoyed attending, in company with his

[1] English version of the memorial address delivered at a meeting of the R. Danish Academy of Sciences, Copenhagen, Mar. 14, 1924, and published in its original form in "Oversigt over det Kgl. Danske Videnskabernes Selskabs Forhandlinger, June, 1923–May, 1924," Copenhagen, 1924.

brother, the scientific meetings of the Natural History Society, repeatedly giving lectures there, after the death of his brother he withdrew, lived by himself, and had intercourse with his colleagues only during the working hours at the museum, which he kept with minute punctuality. It was never possible to make him attend any meeting, still less any social gathering. He could not even think of being away from his home during the evening. In this peculiarity we must seek the reason for the fact that Winge, who was, in 1910, elected member of the Academy of Sciences, never attended a meeting, a circumstance that caused him to be rather little known to all those who did not get an opportunity of coming into touch with him through their work. But if anybody called on Winge in his home, in his pretty villa on Lemche's Road, in Hellerup, they might be sure of a very hearty welcome; and all those who have had an opportunity of knowing him more intimately—he did not in any way shun people—commend him as one of the most high minded and disinterested of mankind. He was so fortunate as to be financially well situated, so that the smallness of the salary he received did not inconvenience him; he could afford to provide himself with an excellent library and even to pay the expenses of illustrating his papers when the Periodical (Vid. Medd. Dansk Naturh. Forening, København) could not afford it. He was fortunate enough to be able to devote his life to his science alone—he cared little for anything else. He was satisfied with his subordinate position, did not aim at power or honor, and rather preferred being exempt from any official recognition in the form of titles or rank, only wishing to live as quietly and unnoticed as possible. But when truth and right were concerned he did not hold back, and on a certain occasion he did not hesitate to put his position at stake, in order to prevent something that he regarded as improper.

Immediately after receiving his master of arts' degree, Winge made a trip to Italy and Switzerland, a journey which he ever afterwards remembered with great delight. But since then he was probably never outside of the boundaries of Denmark. Besides some minor journeys in consequence of the investigations of the kitchen middens from the Stone Age, in which he took part, he traveled, upon the whole, very little. Only once he went to Ringkøbing Fjord, on account of Rambusch's investigations there, and joined in excursions to "Tipperne" and "Klaegbanken." The rest of the time he stayed at home making small excursions in the environs of Copenhagen, partly on his bicycle. It sounds rather odd to those who knew Winge personally to hear that he used to ride a bicycle; and it must be admitted that he did not look very sportsmanlike in his long, black frock coat and large, black, broad-brimmed hat—the costume which he always wore at the museum, as well as on excursions.

The trip to Ringkøbing Fjord, with Dr. S. Rambusch and Winge, is one of my dearest memories. It was the first time that I had the opportunity of becoming intimately acquainted with Winge, and I was deeply impressed at seeing his excitement and joy over the marvelously rich bird life which makes this particular spot one of the brightest jewels in the natural scenery of our country to the lover of nature. He was not a closet philosopher as one might be inclined to believe from a first superficial impression. It was not merely old bones that he knew and could decipher, perhaps better than anybody else in the world; living nature as well he knew thoroughly, and loved it, one might almost say, fanatically * * *. The birds and the small mammals attracted him especially. At home, at his villa, he had bought the adjacent site in order to let it remain as waste land, a sanctuary to birds and small mammals, and here, where no hand was ever allowed to "put things in order," but where the weeds were free to spread, obeying only the laws of nature, he found great enjoyment in observing the amazingly rich animal life stirring in this small sanctuary in the middle of the closely-built villa quarter. You will understand from this that Winge must have been an ardent advocate of all protection of nature. He fought particularly against the hunters in their fatally misconceived war of extermination on all birds of prey, as his brother had previously done in his excellent booklet "Jaegernes skadelige Dyr" ("The Hunters' Noxious Animals"), a new edition of which Winge took charge of and paid for in 1911.

We have a very beautiful illustration of Winge's love of nature in his will, in which he directed that a fairly large part of his fortune (70,000 kr.) is to be used for purchasing a nature park in the neighborhood of Copenhagen, where animal life shall be absolutely protected. He has entrusted the University with this matter, which will, we may be sure, be carried out in strict accordance with his wishes.

One of the things that made the greatest impression on us who knew Winge was his phenomenal knowledge of the birds' voices. Not merely did he know the song of the various birds, but any sound which they can produce he knew, and understood what it meant—their calling for each other, expression of fear, sounds of warning, etc. Winge knew the birds' language, but he also knew the art of making others understand it. One of the first excursions held by the Natural History Association—in 1903—had the object of studying birds' voices under the leadership of Winge. Several of us who joined this excursion remember, I feel sure, with deep joy how he stood there in the freshly leaved-out beech wood in "Ermelunden," teaching us the curious trills of the green warbler—which reminds one of a rattling silver coin. He then led us to "Hvidegaard"

burial mound, told us about the sorcerer of the Bronze Age, whose grave had been found there, who had with him in his grave his leather box with the magic charms, a claw of the goshawk, and several bits of animal remains and pebbles, doubtless taken from the stomach of the same bird, which was probably regarded as sacred by the people of the Bronze Age. He further told about the finds in a Bronze Age grave (Aalestrup Heath) where there had been discovered, together with the remains of a young, scarcely full-grown man, remains of birds, from which it was evident that six pairs of wings of the jackdaw and two pairs of wings of the crow or rook had been laid on the funeral pile, together with the dead man, evidently with the idea that these black wings should carry the soul to the unknown land. Winge had a profoundly poetical mind, and few are those, I think, who, more than he, have understood and enjoyed the beauty of nature, be it purely the beauty of the landscape in the extensive meadows at Ringkøbing Fjord, or in the beech wood just out, or in the chorus of birds in springtime.

His first scientific paper Winge published as an undergradute when he was but 20 years of age. It is a very careful comparative osteological anatomical description of the crania of the mole and shrew, which does not, however, show in any marked degree the characteristics of the future investigator. On the other hand, already in his next paper "Om graeske Pattedyr" (On Greek Mammals) ("Vid. Medd." 1881) we have Winge complete, with all his excellent qualities, his exactness in every detail, his careful observation of the habits of the living animals, his remarkable knowledge, the very carefully considered presentation, the interesting notes, and not least, his emphatic Lamarckism. * * * Especially interesting is his demonstration here of the fine correspondence between habits and morphological features in the structure of the teeth, the cranium, and the whole body of the field voles, characteristics which, according to Winge, have arisen entirely as a result of their habits. We have here the train of reasoning that runs like a red thread through Winge's whole life work: his pronounced Lamarckism. To him there was no doubt but that all the morphological and anatomical characteristics of the animals had arisen as direct effects of their habits. We get the impression (I never discussed it with him directly) that he was even of the opinion that the very animals consciously operated to develop themselves, each in its special direction. A few quotations will show this: "In order to be able to watch and to get long limbs which might in time carry them away from their enemies, the ungulates have from the very outset practiced rising on tiptoe." "What has happened on the way from reptiles to true mammals is this, that a series of alterations have arisen in conse-

quence of a more active life. Appetite for food has started evolution; their own voracity and the fear of the voracity of others have made lizard-like reptiles use all their faculties with special diligence, and they have worked their way forward to become mammals." It is training and use that condition development. The necessary premise is, of course, the inheritance of acquired characters, and about this Winge had absolutely no doubt. True enough, it is at present more common to deny the inheritance of acquired characters, as being at variance with our experience. The problem can—in my opinion—by no means be said to be solved as yet. Much may be said, and is said, for as well as against it. I shall, of course, not here enter more in detail on this question which is the foundation of all Lamarckism. But it may probably be admitted that it is not likely that there will be many who can fully share Winge's point of view on this matter.

The year after, 1882, Winge published a paper "Pattedyrenes Tandskifte, isaer med Hensyn til Taendernes Former" (Tooth succession in mammals particularly with reference to the forms of the teeth), which may well be designated as one of the best works ever produced on this important subject. Had it been published in one of the universally known languages it would at once have procured for Winge recognition as one of the most prominent mammalogists. As it was, it took a good deal of time before it was known at all among the investigators of foreign countries. But Winge insisted that he would compel the naturalists of foreign countries to learn to read Danish, with the result that, even at present, after the course of half a century, this treatise is only partly known—and partly misunderstood, on account of the language. It is not necessarily given to every naturalist to be a linguistic genius, and it is not to be expected that they should sacrifice half their lives in learning all the possible—or impossible—languages in which scientific papers may be published. The result is that such works are ignored, to the harm not only of the author, but often also to that of science. This was exactly the case here.

The dentition in mammals and its phylogenetic development has been the subject of detailed studies from many points of view, and several theories have been advanced concerning this matter. The theory which has won the most followers was first outlined by two American paleontologists, Cope and Osborn, and is named after them. It coincides in the main with Winge's theory though differing in important particulars, but is distinguished by a much more cumbrous terminology. If Winge's paper had been published in one of the universal languages, his theory and his name would no doubt have won the acknowledgment that fell to the share

of Cope and Osborn; and many a theory, more ingenious than successful, as to the explanation of dentition would have been made superfluous. * * * I shall try in a few words to give an idea of what Winge's theory aims at.[1] In the reptiles from which mammals are descended the teeth were not used for chewing, only for catching and holding or rending the prey that was usually devoured whole. True mastication of food seems to have originated within the mammalian group and this involved a further development, partly of the chewing muscles, partly of the teeth. Of special importance is the appearance in mammals of an entirely new muscle, the masseter, which through its attachment somewhat in front on the lower jaw, lends increased strength to the movements of the jaw. During the chewing and cutting process the lower jaw is moved not only straight up and down, but also slightly to the sides, and forward and backward, thus bringing each of its teeth alternatively into contact with the two teeth of the upper jaw between which it fits when the chewing apparatus is at rest. These contacts stimulate the teeth to the development of secondary cusps, a process which chiefly affects the more posterior teeth, that is, the ones which receive the muscle power most strongly. Whereas in reptiles the teeth are simply conical, they are in the oldest mammals three-cuspidate (not counting some aberrant forms). The middle cusp is the largest and the primordial one, the two others are the new additions due to contact stimulation. As an inheritance from the reptiles, the lower jaw is slightly narrower than the upper jaw. Hence the teeth of the lower jaw must slide along the inner side of the teeth in the upper jaw. The act of chewing will thus have the greater effect on the outer side of the lower teeth and on the inner side of the upper teeth. Through the continuation of this influence the three-cusped primitive mammalian teeth are further stimulated to the formation of new cusps, as a rule two of them, which, accordingly, appear on the outer side of the lower teeth and on the inner side of the upper teeth. Whereas the lower teeth, set as they are in the narrow movable mandible, do not as a rule develop any further, still another pair of cusps may appear on the inner side of the upper teeth, which are broadly supported in the solid maxilla. * * * At the same time the three original, primitive mammalian cusps may be reduced, being less used, and, at last, they may completely disappear. The various cusps now being numbered, though in Winge's system and not in strict accordance with their phylogenetic succession (the primordial cusp bears the number 2), we have a means through which we can indicate, with full certainty,

[1] As this paper in the English version is intended for a somewhat different class of readers than that to which the original Danish text was addressed, this paragraph has been slightly enlarged, with Dr. Mortensen's consent, by Mr. Gerrit S. Miller, jr.—Ed.

how the various cusps in different mammals correspond to one another, and how the various tooth forms have developed from one another. In the diagram introduced by Winge we have an exceedingly simple, but absolutely clear method of indicating the morphological value of every tooth form.

It may perhaps appear somewhat exaggerated to attach such great importance to this unraveling of tooth relationship. It is, however, by no means so. The teeth in mammals reflect in such high degree the habits and organization of the entire creature that one may, as it were, from a molar alone draw conclusions as to the whole animal. The teeth [within certain limits][1] form the main foundation for recognizing generic interrelations. Moreover, teeth are particularly fit for being preserved in a fossil condition; of the oldest forms of mammals, we know scarcely more than the teeth, at most now and then a fragment of a lower jaw. To have given the correct deciphering of the tooth structure of mammals, is, therefore, a scientific achievement that is in itself sufficient for securing its author imperishable honor. But this is not Winge's only achievement.

In 1888 appeared the first volume of "E. Museo Lundii," the large work on Dr. P. V. Lund's collections of fossil bones from the limestone caves of Brazil, published at the expense of the Carlsberg Foundation. To this volume Winge contributed a large memoir "Jordfundne og nulevende Gnavere" (Rodents, fossil and recent). This is the first of a long series of memoirs in which are successively worked out: bats, marsupials, monkeys, carnivores, ungulates and edentates; the last of them appeared in 1915. While Volume I contains contributions by Reinhardt, Lütken, Oluf Winge, and Søren Hansen, the whole of the rest of the work is exclusively Herluf Winge's—truly a monumental accomplishment that will secure to Winge a place of honor among paleontologists and mammalogists, carried out, as it is, with the greatest care and exactness, and with an immense learning. While the first five of these memoirs are accompanied by a French résumé, the two last, and largest, are exclusively in Danish.

This work alone would be designated as a great life work. But Winge has yielded much more. Let me first mention that from 1891–1910[2] he took charge of the annual report on the birds at the Danish lighthouses. Originating in England in 1879, an arrangement was introduced in Denmark in the middle of the eighties, mainly on the initiative of Oluf Winge and by means of a small annual grant from the Government, by which all the birds that fall at the Danish lights are to be forwarded to the Zoological Museum for

[1] The words within the brackets were added by Mr. Gerrit S. Miller, jr.
[2] In the Danish text erroneously 1906.

scientific identification. This is a far better plan than the English one, according to which the lightkeepers merely forward a report on the birds that have been found. Denmark has the honor of being the only country where these researches are carried on regularly. They have yielded very important results, especially in the form of highly interesting information about the traveling of the migratory birds. In this connection I should like to mention that Winge gave, in the work "Danmarks Natur" ("Frem," 1897–1899), an exceedingly beautiful and vivid description of the arrival and departure of migratory birds, a description which has, with perfect justice, been introduced into the Danish reading books of the schools.

In connection with these bird reports I shall only just mention his revision of the birds and mammals of Greenland for the "Conspectus Faunae Groenlandicae" and his book on Danish mammals in "Danmarks Fauna." We may now pass to another main section of Winge's life work: His researches on bones and skeletal remains from the kitchen middens of the Stone Age, and from the graves of the Bronze Age, upon the whole all the remains of birds and mammals from prehistoric times collected by our archeologists and geologists. These researches were of the greatest importance. It was through Winge's researches that we received the first decisive proofs of the fact that the Stone Age comprises two different periods, the older and the younger, the people of the older Stone Age being hunters, those of the younger Stone Age resident agriculturists who kept domestic animals. It is a truly enormous amount of material—hundreds of thousands of bone fragments—that Winge went over and identified with quite a phenomenal certainty; and we are involuntarily seized with admiration for the man who was able to carry through this immensely great and difficult work. Also neighboring countries, both Sweden, Norway, and Finland, applied to Winge for help in similar work, and he was always ready to give his assistance. It is thus not only the zoologists, but to an equally high degree the geologists and archeologists who have reason to remember Winge with the deepest gratitude.

After the completion of all these works—"E Museo Lundii," the works on the birds and the researches on the bone remnants from prehistoric times, it was Winge's purpose to sum up the results of his studies of mammals in a great, comprehensive account of all mammals and their mutual relationships. It was his intention that this work should be, as it were, his scientific testament. * * * It became so, alas, in a more direct meaning than he had probably imagined, as he died before it was finished. He just lived to send out Volume I; Volume II was in print; and the concluding Volume III,

fortunately, also was so nearly ready that it can be published quite unaltered, in full accordance with his plan. Winge himself paid the expenses of the publication, and he has also seen to it that the necessary means for meeting the remaining expenses are available. It is to be regretted that the work is written in Danish (without any summary in a foreign language), because it will thus be cut off from gaining the recognition in international science that it ought to have as the comprehensive presentation of the results that one of the most eminent of mammalogists had reached through the indefatigable and conscientious work of a long life, and through a unique mass of learning and an acute valuation of all characters. In an obituary of Winge in "Nature" (29.XII.1923) this work is characterized as "the finest, most comprehensive and most inspiring technical account of the class mammalia that has ever been written."

Not being a specialist in Winge's domain, I have great satisfaction in being able to lay before you the opinion of one of the most prominent foreign authorities in this field, namely of our member, Prof. Max Weber, of Holland. He wrote me, immediately after my informing him of the death of Winge, a letter that I beg to quote in extenso (in translation): "Your letter has filled me with sorrow through the deeply sad news that Winge has suddenly departed from life. A few days before receiving your letter I had received from Winge himself Part I of 'Pattedyr-Slaegter.' I was greatly delighted thereby, because, although the book is in great part a reprint of the comprehensive main sections of his extremely valuable mammalogical studies in 'E Museo Lundii,' these main sections are, however, worked up to date, whereby they become of very immediate importance. * * * I was just about to thank Winge for his gift when your letter came. It gives me, at least, the hope that the material for the following volumes lies ready. It would gladden my heart for the sake of mammalogy, if it were so. For our knowledge of mammals is exceedingly indebted to Winge. Through the originality of his mind, his extensive knowledge, his sharp criticism, the logical working out of his views, he decidedly belonged among the first mammalogists of our day. * * * As a young graduate I frequently visited Norway; I was then interested in the writings of the Sars, father and son, and learned to read Norwegian. In this way also Danish zoology was opened up to me, and I discovered how many treasures lay concealed in Danish garb. I thus became an admirer of Danish zoological work. It was therefore a source of gratification to me to be able to bring H. Winge's 'Om Pattedyrenes Tandskifte' of 1882, which was practically unknown in non-Scandinavian circles, into full daylight, as it deserved, and to point out that Winge is the real forerunner and origi-

nator of the ideas about the evolution of mammalian teeth, as they are represented in the Cope-Osborn theory, which has grown so famous. Unfortunately, his numerous later writings about mammals shared the same fate and did not become as well known as they deserved. I have always been striving to call attention to their great importance. The Danish language was a hindrance to making them known in wider circles, not to speak of including them in the mammalogists' every day literary apparatus. This has doubtless been to the great harm of science. * * * As I had the privilege of knowing Winge personally, I know his reluctance to publish in another language than his mother tongue. I can thus imagine that there may be ethical obstacles in translating into another language his 'Pattedyr-Slaegter,' which is, in reality, a kind of scientific testament. Otherwise a translation of 'Pattedyr-Slaegter' would be a 'monumentum aere perennius,' which many might admire, and which would be of use to many, while in its Danish garment it is confined to a small circle of admirers."

I hope with these words to have given you an impression both of Winge's noble personality and of his exceedingly great contribution to Danish science. At the Zoological Museum, to which he consecrated his powers from his earliest youth to his last day, nobody will for the present be able to fill his place. We, his colleagues, can never forget him, and also here in the Academy of Sciences that had the honor of counting him among its members, we shall cherish his memory.

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